Fire Protection Analysis for the

Tritium Engineering Building

FPE 596

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Statement of Disclaimer

Keywords: Life Safety Code, RSET, ASET, Performance-Based Design, Fire Dynamics Simulator (FDS), NFPA, Fire Dynamics, Pathfinder, Building Code

Executive Summary

This report analyzed several different aspects of the fire protection and life safety strategy for the Tritium Engineering Building (TEB) at the Savannah River Site in Aiken, SC. The TEB is a single-story, Type IIB building that primarily houses engineering and technical staff. The building is approximately 15,560 ft^2 and consists of two large “open areas” enclosed by hard-wall offices. Modular workstations are located in both “open areas” and accommodate the majority of the building occupants. This analysis provided both a prescriptive and a performance-based approach for analyzing fire hazards within the building. The prescriptive-based analysis evaluated the building for compliance with nationally recognized codes and standards. The performance-based analysis evaluated the building using selected performance criteria.

The prescriptive analysis was divided into four sections that evaluated building compliance with nationally recognized codes and standards. These sections include an analysis of building construction and fire resistance, automatic fire suppression, alarm and detection, and life safety. This analysis concluded that the TEB complies with nationally recognized codes and standards in these areas.

The performance-based analysis considered three design fires and determined whether specific safety objectives were met. These design fires included a fire in the conference room near the main entrance, a fire in the centrally-located break room, and a fire in one of the building’s “open areas”. The fire in the “open area” was determined to be the most challenging and selected for a detailed analysis. This portion of the analysis included an evaluation of occupant safety by establishing tenability criteria that were used to define the threshold at which occupants are no longer considered “safe”. The tenability criteria in this report were limited to three environmental factors that can cause harm to occupants during a fire: carbon monoxide (CO) concentration, temperature, and visibility. A fire was modeled inside one of the TEB’s open office areas and egress modeling was used to determine the amount of time required to evacuate the building. This time was then compared to the time it took for the tenability criteria to be reached. This analysis concluded that occupants needed approximately 514 seconds to evacuate and that the tenability criterion for visibility was exceeded at approximately 214 seconds, suggesting that occupants may not have sufficient time to evacuate safely. The tenability criteria for CO concentration and temperature were not exceeded within the time needed for evacuation.

Fire modeling was also used to examine the structural performance of the roof support structure under prolonged fire exposure. This evaluation was primarily in consideration for first responders and aimed to conclude whether the building should be entered during firefighting operations. This analysis concluded that the structural integrity of the building was not at risk when examined under the conditions generated by the proposed design fire.

This analysis resulted in one recommendation regarding the mounting height of the visible notification devices in the building open areas. Though compliant with the installation

requirements of NFPA 72, the mounting height of the visual notification devices is below the height of the workstation walls. It is recommended that these devices are raised or supplemented with ceiling mounted devices to provide sufficient notification to occupants in these areas.

Overall, this analysis concluded that the Tritium Engineering building is compliant with the prescriptive requirements set forth in nationally recognized fire protection codes and standards and that the TEB fire safety strategy is sufficient.

Table of Contents

FIGURES

Tables

Definitions

TEB	Tritium Engineering Building
SRS	Savannah River Site
SRNS	Savannah River Nuclear Solutions
SRTE	Savannah River Tritium Enterprise
CD	Candela (Strobes)
NFPA	National Fire Protection Association
LSC	Life Safety Code
IBC	International Building Code
AFF	Above Finished Floor
RSET	Required Safe Egress Time
ASET	Available Safe Egress Time

1 Building Overview

The Savannah River Site (SRS), located just outside of Aiken, South Carolina, was once home to several nuclear reactors that were built during the Cold War era. A few of the reactors remained operational for a time after the end of the Cold War, but all were eventually decommissioned by the end of the millennia. SRS is currently owned by the Department of Energy (DOE) however, Savannah River Nuclear Solutions (SRNS) serves as the current managing and operating contractor, overseeing several missions including nuclear proliferation, remediation efforts, and nuclear deterrence. The Savannah River Tritium Enterprise (SRTE), shown in Figure *1.1*, is a key component in the SRNS mission and is responsible for processing highly-flammable Tritium gas for national security purposes.

Figure 1.1: SRTE Facility

The Tritium Engineering Building (TEB), is an administrative facility that houses many of the facility's engineering and technical support employees. It is a one-story building constructed in 2013 to meet the demands of a growing workforce. To keep costs low, the building design and construction was sub-contracted out to specialized companies. The building is fully sprinklered and equipped with partial smoke detection and a fire alarm control panel (FACP).

The highest concentrations of occupants in the building are in the "open areas", indicated in Figure *1.2*. Both of these areas are occupied by a grouping of high-walled workstations. Due to recent on-boarding and a growing workforce, several of these workstations house three people. While these workstations are designed to accommodate three people, originally it was assumed that two occupants would occupy a workstation.

Around the open areas, hard-walled offices line the perimeter of the TEB. These offices also typically house two employees and are reserved for management or senior engineering personnel. The center area that divides the two open areas is comprised of a conference room, a men and woman's bathroom, a few additional offices, and a filing room.

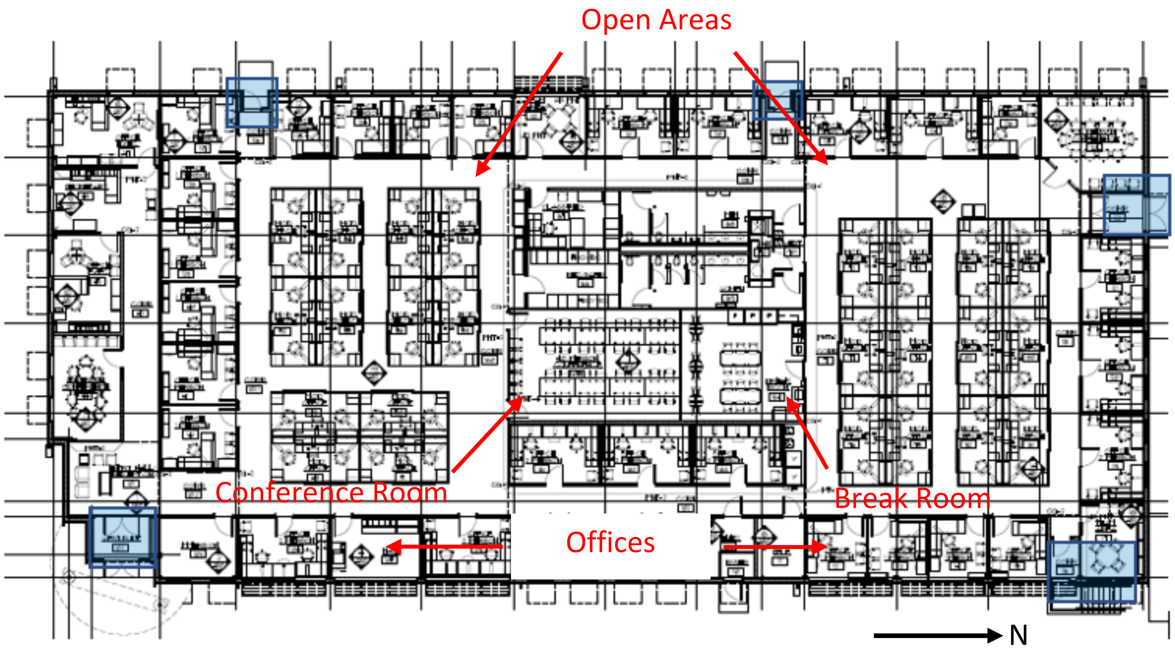


Figure 1.2 Layout of the TEB with Exits Highlighted in Blue

In the first section of this report, the TEB fire protection and life safety systems are compared to prescriptive requirements outlined in national codes and standards. The second section provides a performance-based analysis centered around selected design fire scenarios. The selected design fires aim to tax different elements of the building's fire safety strategy. In order to determine how effective the current strategy is, these design fires generally assume factors that contribute to a worst-case scenario. By assuming a worst-case scenario, we can conservatively conclude whether or not the systems in place will effectively mitigate and control most fires that could occur in the building.

2 Prescriptive Requirements

In the following sections, the features of the TEB will be compared to the prescriptive requirements outlined in applicable national codes and standards. Several of the codes and standards used in the design of this building have been replaced with updated editions. In some cases, the most recent editions of these codes and standards are used instead of the editions used during the time of construction.

2.1 Structural

The TEB was constructed as a Type IIB building under the 2009 version of the International Building Code (IBC). The TEB is classified as a group B business occupancy under the Life Safety Code (LSC) and the IBC, Section 304. The building features a modern design style with an exposed ceiling over the building's "open areas." This section will discuss each structural element of the TEB in more detail. Given that design and construction were governed by the 2009 edition of the IBC, this edition will be cited in this section.

2.1.1 Fire Resistive Construction

TEB was constructed as a Type IIB building, which requires the use of non-combustible building materials but does not require any fire resistive construction or protection of structural elements. The fire-resistance rating requirements for Type IIB buildings are indicated in Table 2-1.

Table 2-1: Fire Resistance Ratings for Type IIB Construction [2]

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Primary structural frame[g] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[f, g]	3	2	1	0	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[e]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and secondary members (see Section 202)	$1^{1}/_{2}$[b]	1[b, c]	1[b, c]	0[c]	1[b, c]	0	HT	1[b, c]	0

Under the LSC, the TEB is not required to have fire resistive construction in exit corridors so long as the building is protected by an automatic sprinkler system for new construction (LSC, Section 38.3.6). There are not any requirements for corridors in existing construction (LSC, Section 39.3.6). Given the absence of credited fire resistance construction, the building is considered as a single "fire-area".

The closest building to the TEB is approximately 120 ft, therefore fire rating of the building's exterior walls is not required, as shown in Table *2-2*.

Table 2-2: Fire Rating Requirements for Exterior Walls

TABLE 602
FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE[a, e]

FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H[f]	OCCUPANCY GROUP F-1, M, S-1[g]	OCCUPANCY GROUP A, B, E, F-2, I, R, S-2[g], U[b]
X < 5[c]	All	3	2	1
5 ≤ X <10	IA Others	3 2	2 1	1 1
10 ≤ X < 30	IA, IB IIB, VB Others	2 1 1	1 0 1	1[d] 0 1[d]
X ≥ 30	All	0	0	0

2.1.2 Exposed Ceiling/Roofing

The roof of the TEB is supported by several diagonal WT8x22.5 T-beams that are connected to an arrangement of exposed steel trusses made of hollow square members (HSS 4x4x3/8). These diagonal trusses are supported by larger W8x10 T-beams that distribute the load of the ceiling/roof to unexposed columns throughout the building. There are two designs for trusses within the TEB, as shown in Figure *2.1*. "Steel Truss Detail #2" was used over the open areas while "Steel Truss Detail #1" is used in the unexposed areas. Both designs utilize the HSS 4x4x3/8 members and W8x10 T-beams.

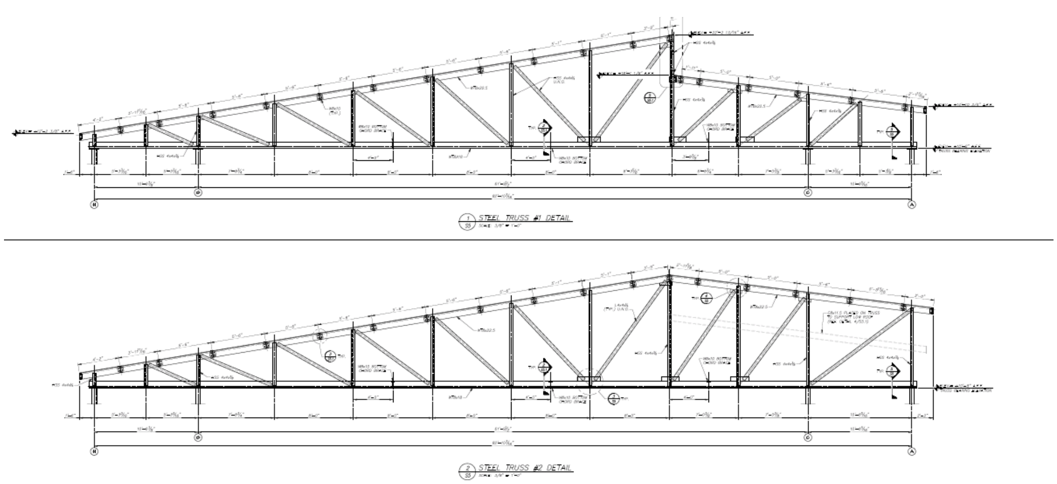


Figure 2.1: TEB Truss Details

All of the lower supporting beams are at an elevation of 10'-8" A.F.F. The weight-bearing columns in the TEB are hollow square columns that are anchored 8" into the concrete foundation. HSS 6x6x3/8" columns were used for interior columns and slightly stronger HSS 6x6x1/4" columns were used for the exterior. All members in this assembly are fastened using ¾" A325 type N bolts.

2.1.3 Walls

There are three designs for the interior partitions of the TEB. The construction of each partition is shown in Figure *2.2*.

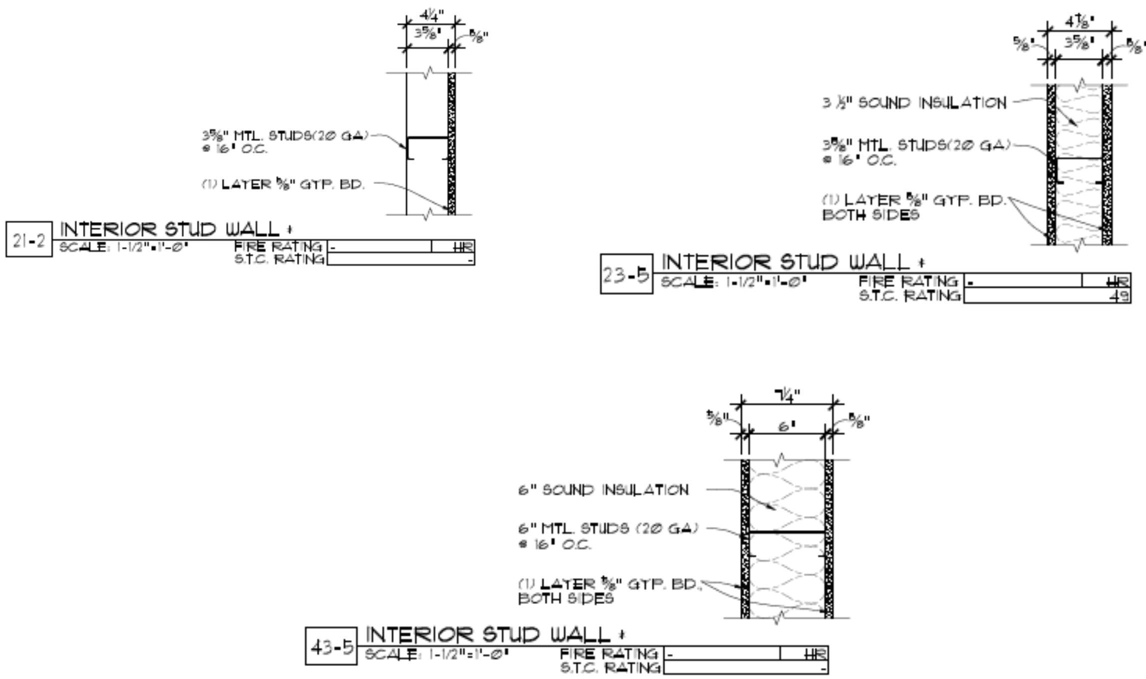


Figure 2.2 TEB Interior Wall Sections

A single layer of 5/8" gypsum board was used as the finishing surface for the majority of the building. This is advantageous for limiting fire-spread since gypsum board is non-combustible. R-11 unfaced insulation was used between the exterior façade and the interior finish. R-11 insulation is a fiberglass material and typically will not burn; however, under fire conditions, R-11 is subject to melting. The sound insulation for the interior partitions, per the building specification, was designed to be fiberglass as well.

2.1.4 Windows, Doors, and Openings

The windows for the offices that line the perimeter of the building are divided into two styles. The first style is a floor-to-ceiling "store-front" design that spans the entire length of the exterior wall (approximately 14'-2" x 10'-4 1/2"). The second is two separated windows, (approximately 4' x 4'-8"). The doors for the TEB vary in construction but are mostly constructed following a hollow metal design.

2.1.5 Allowable Height and Area

As shown in Table *2-3*, the allowable height for a non-sprinklered, Type IIB building is 55 ft. This table also mandates that this building be no more than 3 stories and not exceed an area of more than 23,000 ft^2. Per section 504.2 of the IBC, the installation of an automatic sprinkler system allows an additional increase of 20 ft to the allowable height and provides allowance for an additional story. Criteria for acceptable automatic sprinkler systems can be found in section 903.3.1.1, which states, "Where the provisions of this code require that a building or portion thereof be equipped throughout with an automatic sprinkler system in accordance with this section, sprinklers shall be installed throughout in accordance with NFPA 13 ... " [2]. The addition of an automatic sprinkler system also allows for an increase in the allowable area for the building. Per section 506.3, an increase of 200 percent (46,000 ft^2) is permitted.

Table 2-3: Allowable Heights and Areas [2]

		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT (feet)	UL	160	65	55	65	55	65	50	40
GROUP	STORIES (S) AREA (A)									
A-1	S A	UL UL	5 UL	3 15,500	2 8,500	3 14,000	2 8,500	3 15,000	2 11,500	1 5,500
A-2	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-3	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-4	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-5	S A	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL
B	S A	UL UL	11 UL	5 37,500	3 23,000	5 28,500	3 19,000	5 36,000	3 18,000	2 9,000

A frontage increase was not accounted for in the design of this building. Even though the building appears to have sufficient frontage, an increase was likely omitted given that this building is in a secured (fenced) area. Frontage access by firefighting personnel, while still possible through a vehicle access gate, would likely take an extended period of time and consequently should not be accounted for in the building's design.

The TEB is a single-story building that has a maximum exterior height of 23'-7/8" A.F.F. The building has a gross square footage of 15,510 ft^2. Therefore, all of these values are well within the parameters detailed in Chapter 5 of the IBC.

The mechanical rooms and janitor’s closet total no more than 10% of the building area and are considered “incidental occupancies”. Given that the building is considered a single occupancy, there are no applicable occupancy separation requirements.

2.1.6 Structural Summary

The TEB is in accordance with the applicable structural requirements outlined in the 2009 edition of the IBC. As Type IIB construction with an approved fire suppression system, it is within the prescribed limits for overall height, allowable area, and necessary fire resistance ratings for building materials. The prescriptive requirements that govern the buildings fire suppression system will be examined further in the following section.

2.2 Fire Suppression System

The TEB is equipped with a wet-pipe suppression system that was designed using the 2010 edition of NFPA 13. Though more recent editions of this code have been published, the older edition will be used/cited in this analysis. This section will analyze the prescriptive requirements that governed the original design of the fire suppression system (FSS) and the system's contribution to the overall fire safety strategy for this building.

The riser room for the suppression system, indicated in Figure *2.3*, is located on the east-facing side of the building and can only be accessed from outside.

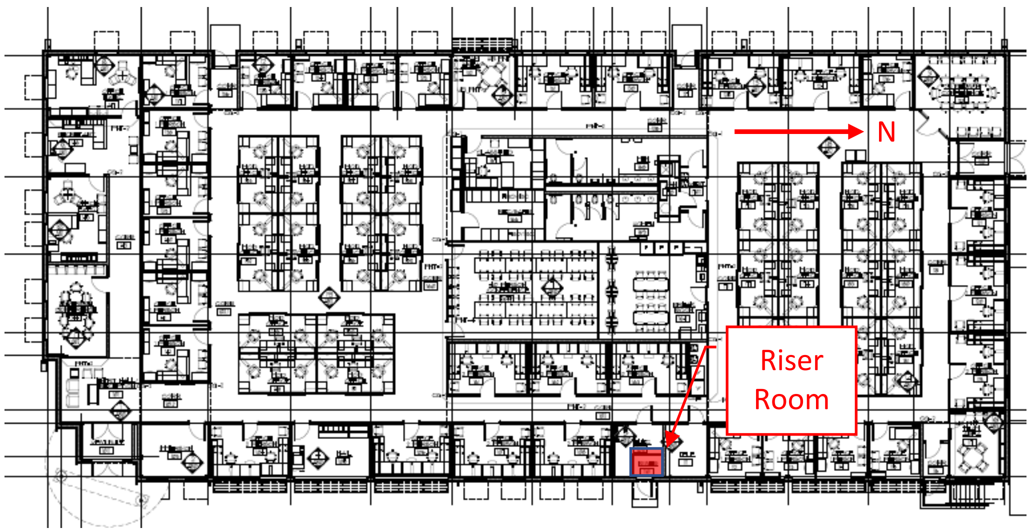


Figure 2.3: Riser Room Location

2.2.1 Design Criteria

The FSS in the TEB was designed using the density/area method. Though most office spaces can be categorized as a "light hazard" per NFPA 13 section A5.2, the TEB was split into two different hazard occupancies. The majority of the building is classified as "Light Hazard" with the exception of the electrical closet and janitor's closet (ref. Figure *2.4*) which are classified as ordinary hazard group 1 (OH1). This designation of OH1 implies that the designer anticipated a higher heat release rate (HRR) from fires in these spaces. It is assumed that these spaces were classified with the higher occupancy classification as a conservative measure.

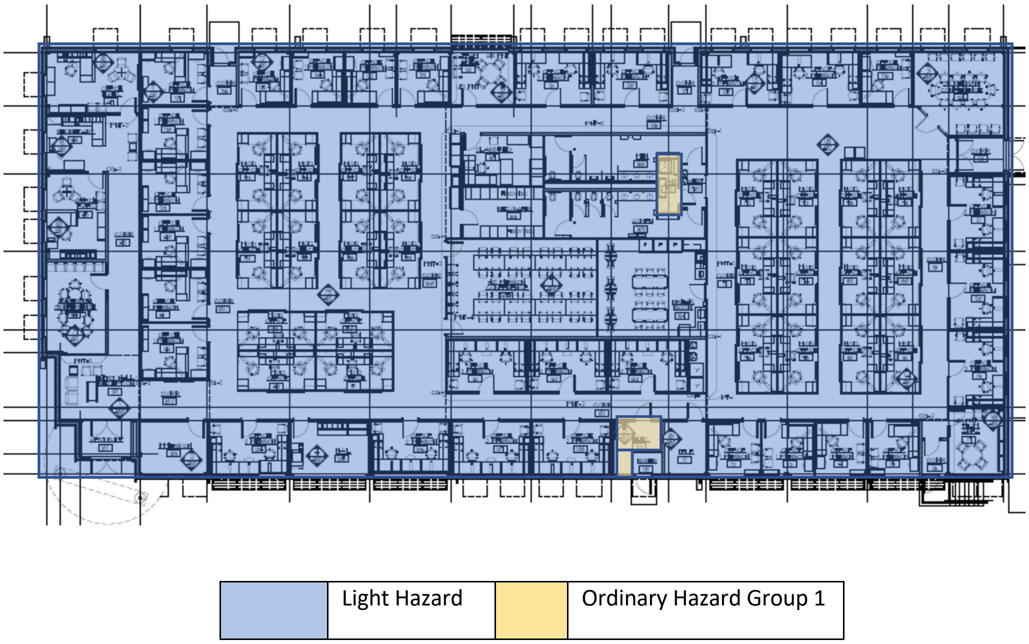


Figure 2.4: Occupancy Classifications for TEB

Using the density/area curves from NFPA 13, Figure 11.2.3.1.1 and hose steam allowances in NFPA 13, Table 11.2.3.1.2, the design parameters were determined and are shown in Table *2-4*.

Table 2-4: Design Densities

Occupancy Classification	Area [ft^2]	Density [gpm/ft^2]	Hose Stream Allowance [gpm]
Light	1,500	0.10	100
Ordinary Hazard Group 1	1,500	0.15	250

For buildings with multiple occupancy classifications, NFPA 13, Section 11.1.6.2 (3) grants an exception for using the primary occupancy so long as rooms with higher classifications total no more than 400 ft^2. The rooms designated as OH1 total no more than 150 ft^2, thus the TEB can be calculated as a light hazard occupancy. In review of the building drawings, the TEB was designed using a 250 gpm hose stream instead of the allowed 100. This is likely a result of requirements within DOE facility standards.

Lastly, the total floor area of the TEB is approximately 15,510 ft^2 which is within the protection area limitation for light hazards specified in section 8.2 of NFPA 13.

2.2.2 Sprinkler Coverage

The roof of the TEB gradually slopes upward to a peak, however the two sides of the roof have different slopes. For this reason, the peak of the room is slightly off-set from the center of the building, as shown in Figure *2.5*. The slope on the West side of the building is shown to be 2:12 (approximately 9.5°). On the East side of the building, the slope is shown to be 1.5:12 (approximately 7.1°). Per the specification sheet for the upright sprinklers these sprinklers are listed for roof slopes no more than 9.5° and were therefore appropriately selected for the space.

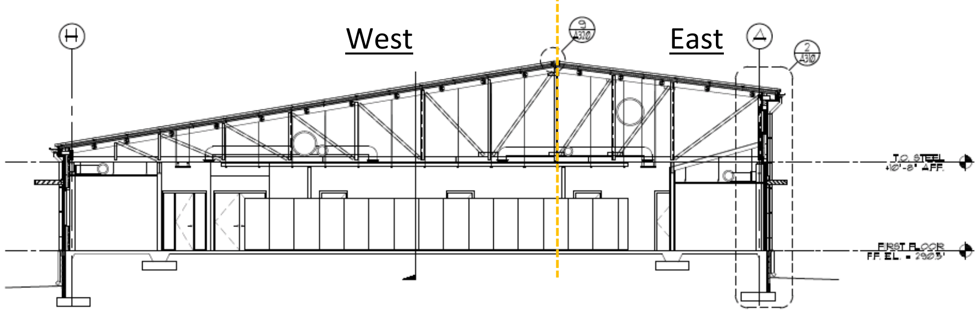


Figure 2.5: Section View of TEB

Sprinklers are installed following two configurations in the TEB, as shown on the sprinkler piping diagram shown in Figure *2.6*. In the walled offices, conference rooms, and break room, semi-recessed K-5.6 pendent sprinklers are installed under a suspended ceiling. In cases where pendent sprinklers are used, Flexhead connectors are used to connect to branch lines. Over the two open areas, K-11.2 upright sprinklers are used.

According to NFPA 13, Table 8.6.2.2.1(a) the maximum spacing for upright and pendant sprinklers is 15 ft. This spacing is followed in most areas in the building with the exception of those on separate branch lines over the “open areas”. The distances between branch lines vary; but, in one particular case, the distance between two branch lines is 15’-8”. The specification sheet shows that the VK532 sprinklers are “extended coverage” sprinklers. According to the specification sheet, when used for a “light hazard”, these sprinklers are UL-listed for a max spacing of up to 20 ft x 20 ft (depending on the available water supply). This is allowable per section 8.3.1.1 of NFPA 13 which states, “Sprinklers shall be installed in accordance with their listing”. Therefore, it can be concluded that the sprinklers in the building are designed in accordance with NFPA 13.

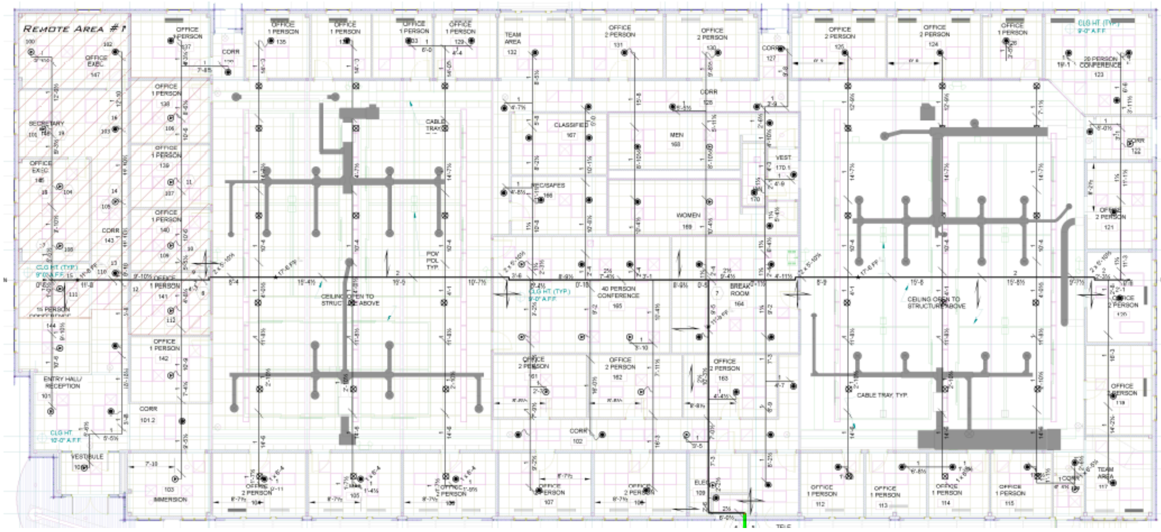
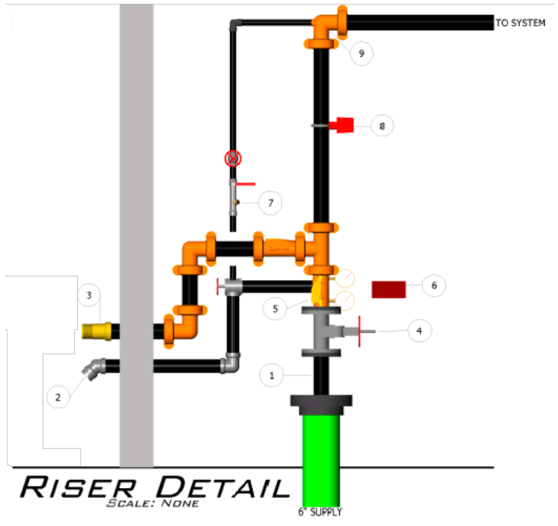


Figure 2.6: Sprinkler Piping Diagram

NFPA 13, section 8.5.2.2 requires that the area of coverage for any sprinkler must not exceed 400 ft^2. According to NFPA 13, section 8.5.2, the protection area for a single sprinkler can be determined by multiplying the maximum distance to an adjacent sprinkler (on the same branch line) by the perpendicular distance to a sprinkler on a neighboring branch line. This building does not have uniform sprinkler spacing, but, in the most extreme case, the maximum sprinkler coverage area is approximately 240 ft^2.

2.2.3 Riser Components

The riser for the TEB is located in a separate room that is only accessible from the building's exterior. The riser components include those shown in Figure *2.7*.



Legend			
1	6” x 2 ½” Flange Spool Piece	6	6-Capacity Spare Sprinkler Head Cabinet
2	2” Main Drain Outlet and Valve	7	Inspectors Test Valve
3	2 ½” Single FDC w/ Automatic Ball Drip	8	2 ½” Flow Switch
4	2 ½” OS&Y Valve with Tamper Switch	9	2 ½” Elbow to 1” Inspectors Test
5	2 ½” Viking Check Valve		

Figure 2.7: TEB Riser Components

This riser is equipped with commonly used components including an OS&Y control valve and related tamper switch, test drains, etc. A vane-type flow switch with an adjustable retard function is used as the primary means of activation for the fire alarm and detection system. In order to prevent nuisance alarms generated by spurious pressure fluctuations in the water supply, the retard delays activation of the fire alarm for a specified period of time.

Typically, backflow preventers are required for fire suppression systems that are fed from municipal water supplies. Given that this is a dedicated fire service main, backflow is not considered a major concern and backflow preventers are not explicitly required. Section 6.2.11 of NFPA 24 requires one of seven different configurations to ensure that service mains are capable of isolation. This building utilizes a post-indicator valve as its primary means of isolation in accordance with 6.2.11(1) [20].

Overall, the configuration of the TEB fire suppression system and sprinkler spacing is in compliance with Chapter 8 of NFPA 13.

2.2.4 Water Supply Analysis

The FSS for the TEB is supplied by a dedicated underground fire service main that serves multiple facilities over approximately 475 acres. The supply main is fed from two above-ground water supply tanks each with a capacity of approximately 580,000 gallons. There are a total of three fire pumps; one electric that serves as the primary pump, and two identical standby diesel pumps. The pumps are rated at 2500 gpm at 118 psi and 2500 gpm at 120 psi, respectively. A jockey pump is also used to make up minor pressure losses resulting from small leaks in the distribution piping. Figure *2.8* and Figure *2.9* display the location of the tanks and pump houses relative to the TEB.

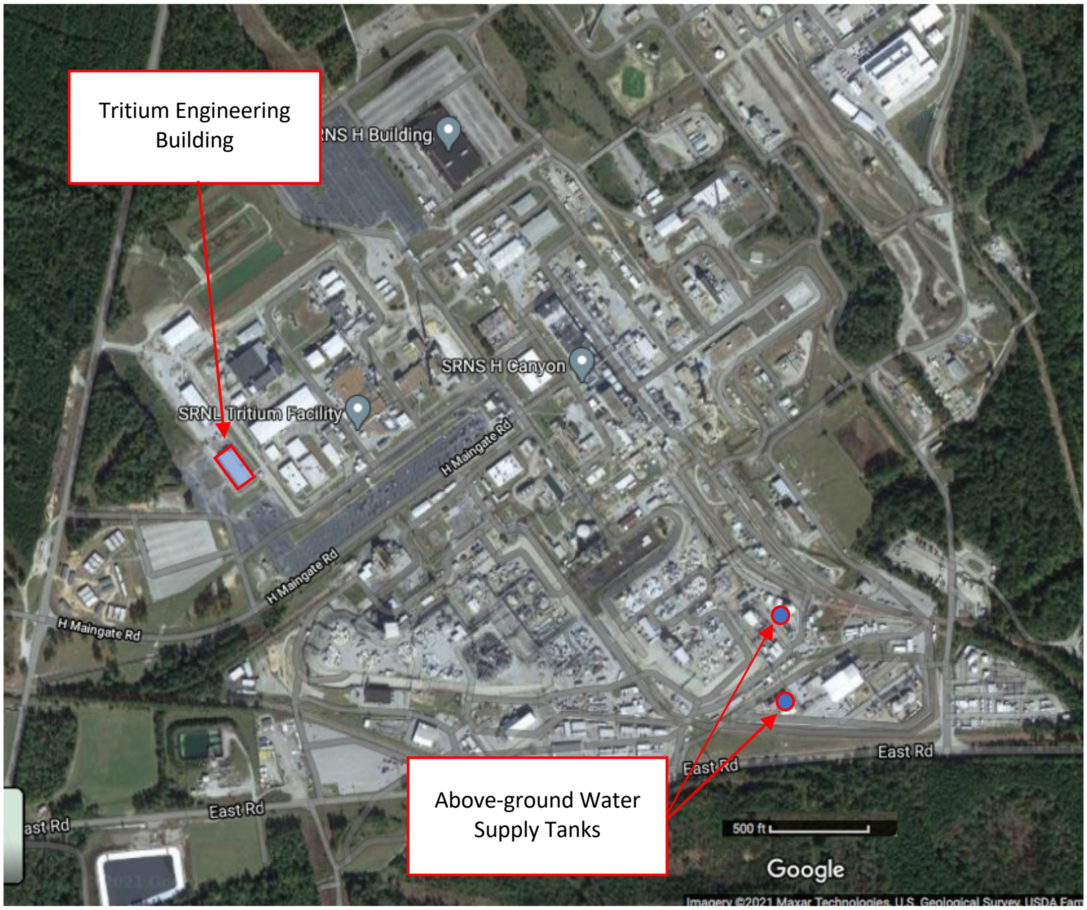


Figure 2.8: Fire Water Supply Overview

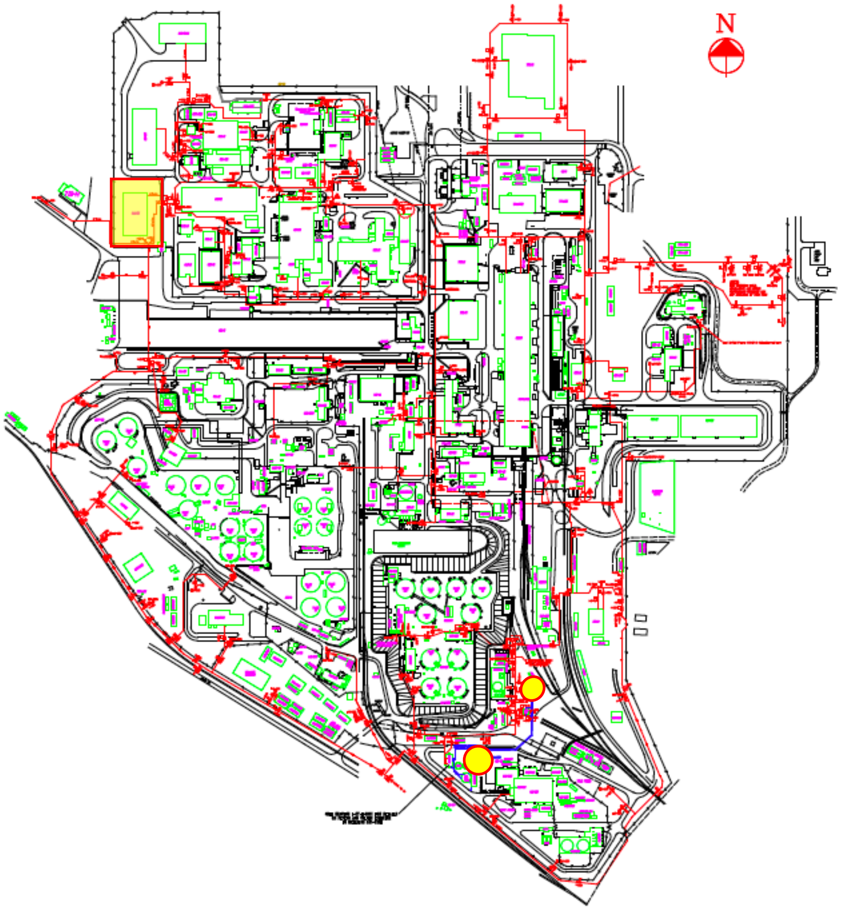


Figure 2.9: Underground Fire Service Main Piping Diagram

The Tritium facility has three alternate inlets from the dedicated underground fire service main, as indicated in Figure *2.10*. Throughout the service main, post-indicating valves (PIVs) are used to isolate branches of the system for maintenance. PIVs near the Tritium inlets are normally open and are visually inspected on an annual basis.

There are multiple fire suppression systems that provide protection to the buildings within the Tritium facility. The location of the test/flow hydrants were selected near the building with the highest sprinkler demand. Because this is a dedicated water supply, it can be reasonably assumed that so long as the demand is met for the most hydraulically demanding building, the water supply should be sufficient for all other buildings within the facility.

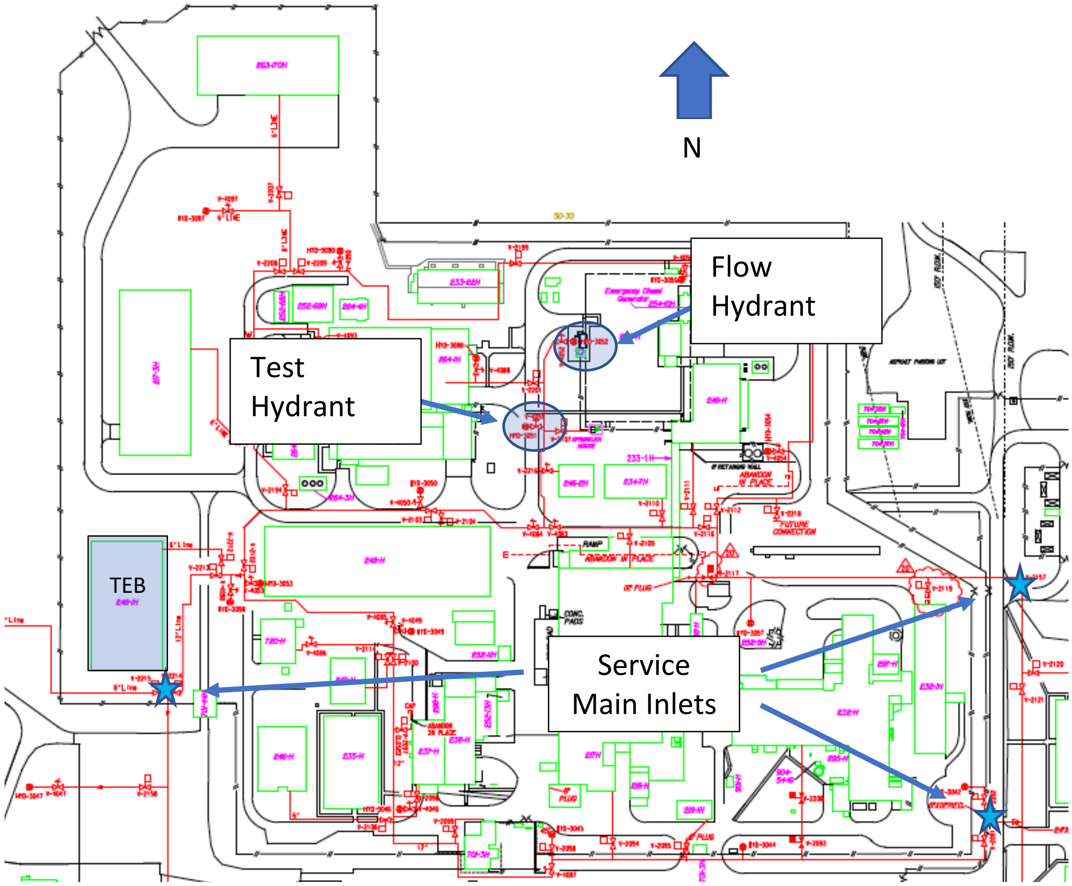


Figure 2.10: Fire Water Main Inlets to the Tritium Facilities

Referencing the most recent flow test data, a total of four flow tests were performed using the same test/flow hydrant. Theses test results are summarized in Table *2-5*. Tests 1-3 isolated each inlet by closing the other two alternate inlets. The fourth test was performed with all three inlets open.

Table 2-5: Tritium Facilities Hydrant Flow Test

Inlet (Open)	Static Pressure [psig]	Residual Pressure [psig]	Flow [gpm]
West	144	133	1284
Southeast	152	132	1284
Northeast	152	120	1216
All	152	136	1284

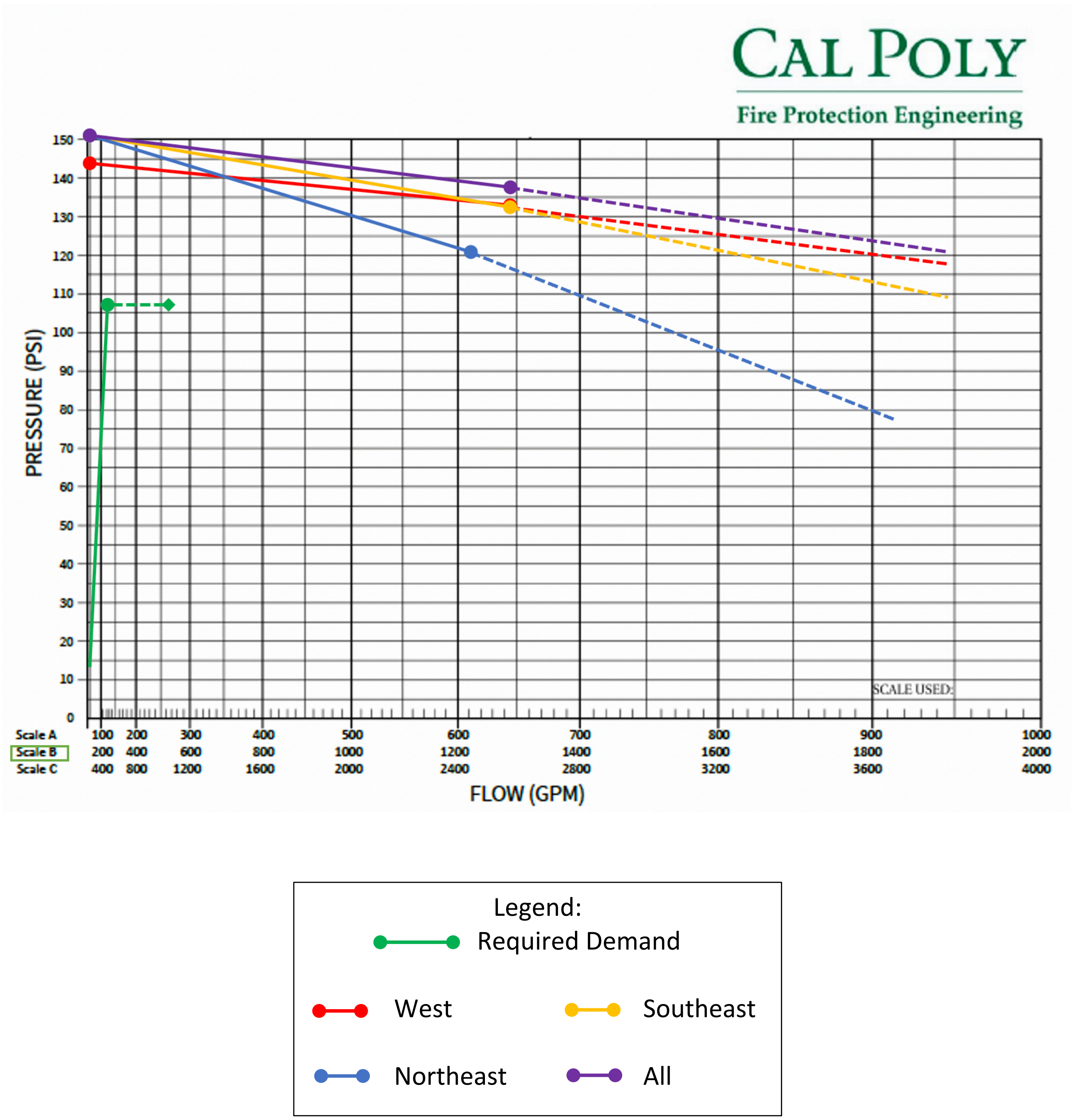


Figure 2.11: Supply/Demand Curve

**The elevation of the sprinkler system above the point of connection was assumed to be 30 ft, which resulted in approximately 13 psi of an elevation head.

Graphing these values along with the system demand provides a visual comparison to ensure the water supply is sufficient. As shown in Figure *2.11*, the demand for the TEB is clearly met. Given that the dedicated water supply feeds multiple suppression systems with higher demands, the high safety margin shown in this figure is expected. The demand for the FSS, as shown in Figure *2.11*, will be discussed further in the following section.

2.2.5 Hydraulic Analysis

The original hydraulic calculations for the TEB were performed using computer software. Though it is unclear what software was used, the HASS calculation software is currently approved for use at SRNS. According to the building as-built drawings, the system demand was calculated to be 272.29 gpm over 109.63 psi.

The remote area for the building, indicated in Figure *2.12*, is over the executive offices. As mentioned in previous sections, this area is light hazard and requires a density of 0.1 gpm/ft^2 over an area of 1500 ft^2.

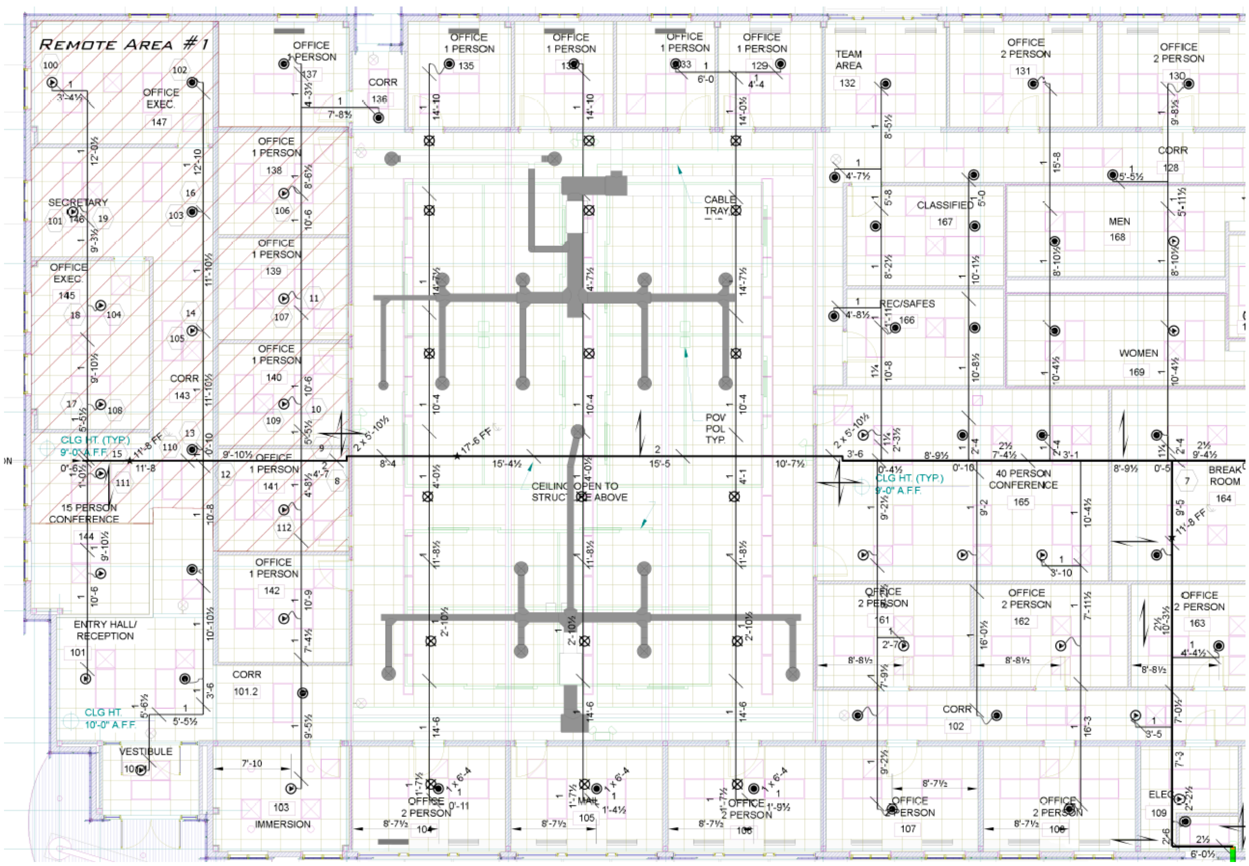


Figure 2.12: TEB Remote Area and Hydraulic Nodes

2.2.6 Inspection, Testing, and Maintenance

Testing of the TEB is currently performed in accordance with the 2017 edition of NFPA 25. The FSS in the TEB is visually inspected quarterly, and tested semi-annually and annually. Inspection, testing, and maintenance (ITM) records are maintained through use of approved procedures that are retained for future reference.

Testing for this building is in accordance with Table 5.1.1.2 in NFPA 25. A summary of the inspection, testing, and maintenance frequencies is shown in Table *2-6*.

Table 2-6: Inspection, Testing, and Maintenance Matrix

Component	Frequency
Inspection	
Pressure Gauges	Quarterly
Supervisory Devices (Tamper Switches)	Quarterly
Water Flow Alarm	Quarterly
Fire Dept. Connection	Quarterly
Pressure Relief Valve	Quarterly
Control Valves	Annually
Hangers/Braces/Supports	Annually
Piping and Fittings	Annually
Sprinklers	Annually
Hose Connections	Annually
PIV (Position)	Annually
Check Valves	5 Years
Internal Piping	5 Years
Test	
Water Flow Alarm (Vane)	Semi-Annually
Main Drain	Annually
Cycle Control Valves	Annually
Supervisory Devices (Tamper Switches)	Annually
Pressure Gauges	5 years
Check Valves	5 Years
Pressure Relief Valve	5 Years
Fire Dept. Connection (Pressure)	5 Years
Maintenance	
Control Valves	Annually
Sprinklers (Replace)	50 years

Additionally, spare sprinkler head cabinets and hydraulic sign information are inspected annually to ensure that all spare parts are on hand and the related system information is correct and available. Annual main drain tests are performed annually to evaluate the condition of the water supply. Test results are compared to previous tests to determine if there is deterioration in the water supply piping from the point of connection. This differs from annual hydrant flow tests which evaluate the adequacy of the water supply (downstream of the point of connection).

After reviewing test procedures for the building, the inspection, testing, and maintenance practices for the TEB were found to be in accordance with the requirements of NFPA 25.

2.2.7 Fire Suppression System Summary

This report evaluated the prescriptive requirements governing the design and testing of the fire suppression system in the TEB. Overall, no deficiencies were noted in the design or performance of ITM activities for this building.

2.3 Alarm and Detection

In this section, the fire alarm and detection system for the TEB will be analyzed and compared to the 2010 edition of NFPA 72, *National Fire Alarm and Signaling Code* which is the established code of record for the building. The components, arrangement, and requirements for operation will be discussed in the following sections.

2.3.1 Detection and Initiating Devices

The TEB is equipped with several types of initiating devices (see Appendix A for specification sheets). These devices are monitored by a model 4100ES Fire Alarm Control panel from Tyco, Simplex-Grinnell, located near the main entrance foyer of the TEB, as indicated in Figure *2.13*. The system is monitored remotely by an on-site central supervising station that has the capability to initiate a fire response if needed.

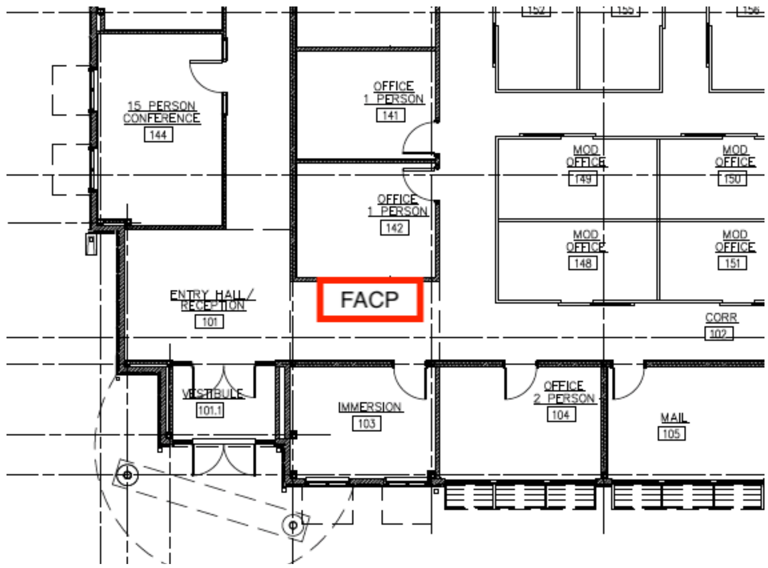


Figure 2.13: TEB Fire Alarm Control Panel

The sequence of operations matrix for the fire alarm control panel is shown in Figure *2.14*. The primary initiating device for the TEB is a vane-type waterflow switch located along the fire water riser. When fire suppression system's sprinklers activate, the flow switch is tripped and an alarm is registered. These sprinklers provide a means of detection, therefore full-scale protection with smoke/heat detectors is not required [5]. With the exception of a few areas, smoke detection was not installed in the majority of the building.

CONTROL UNIT ANNUNCIATION | NOTIFICATION | FIRE SAFETY CONTROL

SYSTEM OUTPUTS

	SYSTEM INPUTS	A ACTUATE COMMON ALARM SIGNAL INDICATOR	B ACTUATE AUDIBLE ALARM SIGNAL	C ACTUATE COMMON SUPERVISORY SIGNAL INDICATOR	D ACTUATE AUDIBLE SUPERVISORY SIGNAL	E ACTUATE COMMON TROUBLE SIGNAL INDICATOR	F ACTUATE AUDIBLE TROUBLE SIGNAL	G ACTUATE APPROPRIATE LOCATION INDICATOR	H ACTUATE ALL AUDIBLE EVACUATION SIGNALS	I ACTUATE ALL VISIBLE EVACUATION SIGNALS	J	K DISPLAY / PRINT CHANGE OF STATUS	L TRANSMIT ALARM SIGNAL TO SUPERVISING STATION	M TRANSMIT SUPERVISORY SIGNAL TO SUPERVISING STATION	N TRANSMIT TROUBLE SIGNAL TO SUPERVISING STATION	O	P	Q	R	S	T	U	V	W	X	AD	AE	AF FAN SHUT DOWN	AG DAMPER SHUT DOWN	AH	
1	SMOKE SENSOR/DETECTOR	•	•					•	•	•		•	•															•	•		1
2	MANUAL PULL STATION	•	•					•	•	•		•	•															•	•		2
3	DUCT SENSOR/DETECTOR	•	•					•	•	•		•	•															•	•		3
4	WATERFLOW SWITCH	•	•					•	•	•		•	•															•	•		4
5	TAMPER SWITCH			•	•			•				•		•																	5
6	POST INDICATOR VALVE SWITCH			•	•			•				•		•																	6
7	FIRE ALARM AC POWER FAILURE					•	•					•			•																7
8	FIRE ALARM SYSTEM LOW BATTERY					•	•					•			•																8
9	OPEN CIRCUIT					•	•					•			•																9
10	GROUND FAULT					•	•					•			•																10
11	NOTIFICATION APPLIANCE CIRCUIT – CLASS A/STYLE Z:																														11
12	WIRE–TO–WIRE SHORT					•	•					•			•																12
13																															13
14																															14

Figure 2.14: TEB Sequence of Operations

There are 3 spot-type photoelectric smoke detectors in the TEB. All of these detectors are located in areas over electrical equipment. The smoke detectors are located in the telephone room, electrical room, and above the FACP as required per section 10.4.5 of NFPA 72. It is assumed that the rationale behind using detectors in the electrical-type locations was related to the elevated hazard of having electrical equipment in unoccupied spaces.

Both the electrical room and the telephone room are shown to have a maximum dimension of approximately 10 ft. NFPA 72 section 17.7.3.2.3.1 states, that for spot-type smoke detectors, "all points on the ceiling shall have a detector within a distance equal to or less than 0.7 times the listed spacing (0.7S)." The maximum spacing of the smoke detectors per NFPA 72 is nominally 30 ft. Upon inspection, it was determined that every point on the ceiling in these rooms was within 21 ft of a detector. Therefore, the placement of detectors in the center of these two rooms complies with the requirements found in the National Fire Alarm and Signaling Code.

Though only one means of initiation as discussed in NFPA 101 38.3.4.2 is required, several additional means of initiation are installed in the building. Pull stations are installed near all of the building exits in accordance with NFPA 101 section 9.6.2 and duct detectors are installed in both of the building's air handling units.

2.3.2 Smoke Control Systems

Based on the requirements found in NFPA 90A (2009), section 6.4.2.1, duct detection would not typically be required for air handling units under 2000 cfm. Both air handling units for the TEB have significantly less capacity than this; however, the collective airflow for the two units is approximately 2,000 cfm and it's assumed that these duct detectors were installed as an additional protective measure.

As shown in the sequence of operations matrix (ref. Figure *2.14*), the activation of duct detectors, along with all other initiating devices in the building, automatically shuts down the HVAC fans and closes the system dampers. There are no additional smoke control systems in the TEB.

2.3.3 Notification Devices

The notification devices in the building are *True Alert* Multi-Candela units manufactured by Simplex (specifications can be found in Appendix A). Audible/visual combination units were selected for use throughout the building except in restrooms, which only have visual notification appliances. All notification appliances will be activated in the event of smoke detection (from either duct or ceiling-mounted detectors), manual pull station actuation, or a waterflow signal as shown in the sequence of operations (ref. Figure *2.14*).

<u>Audible</u>

Per project specifications, the horns were required to be electric-vibrating-polarized type, 24-VDC and capable of producing a sound-pressure level of 90 dBA, measured 10 ft from the horn, using the coded signal prescribed in UL 464 test protocol. Project specifications also required visible notification appliances to be Xenon strobe lights that comply with UL 1971. The *True Alert* Multi-Candela units were found to comply with these requirements.

NFPA 72, Section 18.4.4.1 requires all audible devices to be 15 dBA above the ambient noise level or 5 dB above the maximum sound level having a duration of at least 60 seconds—

whichever is greater. The prescriptive ambient sound level in this building, per table A.18.4.4 in NFPA 72, is conservatively 55 dBA. Therefore, all points in the building must be at or above 70 dBA if ambient sound measurements are not taken. As shown in Table 2-7, the ambient and alarm sound level readings taken during acceptance testing confirm that this building is compliant with this requirement.

Table 2-7: Audible Device Acceptance Testing

SOUND LEVEL SURVEY TEST / RESULTS

Location	Ambient Sound Level[1]		Alarm Sound Level[1]		Pass / Fail[2] (circle one)
Room 106	35,7	db	80	db	Pass / Fail
Room 111	65,5	db	71,1	db	Pass / Fail
Room 164	48,8	db	71,3	db	Pass / Fail
Room 120	41,2	db	70,2	db	Pass / Fail
Room 129	45,8	db	66,5	db	Pass / Fail
Room 147	41,9	db	72,4	db	Pass / Fail
Room 141	38,4	db	72,7	db	Pass / Fail

NOTES:

1. Ambient sound levels and alarm sound levels to be taken with room doors closed.
2. Alarm sound level must be greater than or equal to 15 db higher than the ambient sound level for each location.

<u>Visual</u>

As mentioned, all the visual notification devices in the TEB are multi-candela but all have been set to a 75 cd output. Weatherproof strobes were also identified for placement on exterior walls near entry ways but were omitted in construction due to a later-determined lack of necessity.

The open areas are equipped with horn/strobes located on the west and east walls. The floor area is approximately 46’ 7” x 53’ 9.5” for both open areas. Using Table 18.5.4.3.1(a) for a 54 ft x 54 ft room, the required candelas for two lights are “Unknown”. Therefore, the room must be divided into two separate areas using a 45’ x 45’ “maximum room size”, as shown in Figure *2.15*. Given that the visual appliances are not centered and one 75 cd light is sufficient for a space of 45’ x 45’ ft (Table 18.5.4.3.1a), the use of these two visual appliances is questionable.

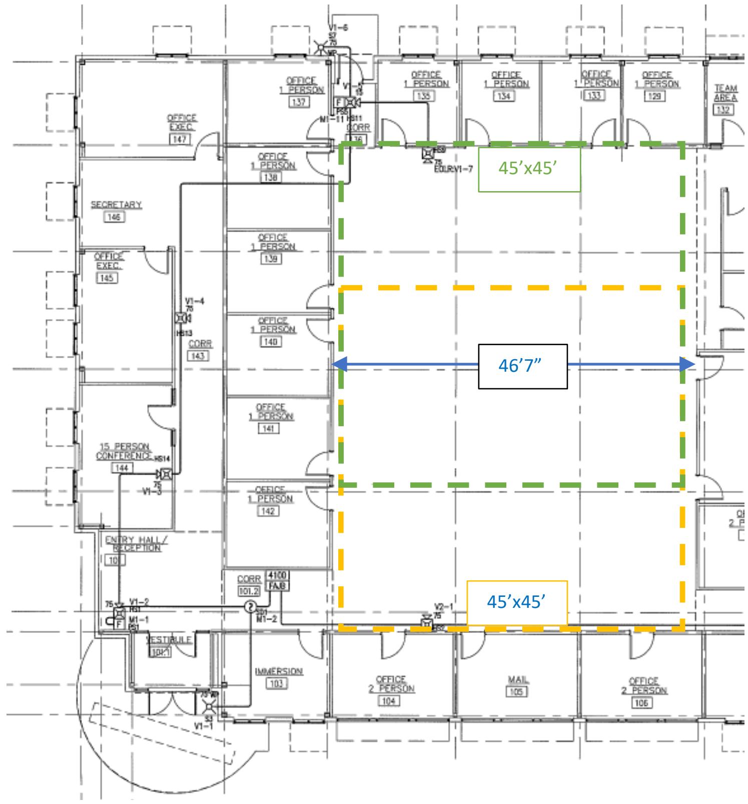


Figure 2.15: Visual Appliance Spacing

The placement of these appliances is also questionable. For both open areas, the appliances are not centered on their respective wall (their coverage area) and are placed directly across from each other. This is not considered to be "best practice" as suggested in sections A.18.5.4.3(c) and A.18.5.4.3(d) in NFPA 72.

Further, both "open areas" have cubicle walls that are approximately 82" in height. The horn/strobe appliances on the surrounding walls were installed using the minimum height requirement of 80", which places the strobes approximately 2" below the top of the cubicle walls. Given this configuration, occupants in cubicles or in the corridors separating cubicles are not within view of any visual appliance and are thus reliant on audible notification. An alternative would be to include ceiling-mounted visual appliances which would increase the overall light output and help to ensure that occupants in the cubicle areas are capable of seeing visual signals.

According to NPFA 72, Section A.18.5.4.4.5, visual notification devices centered in the connecting corridors (between open areas) are acceptable using the requirements outlined in Section 18.5.4.3. The strobes in the corridors are 75 cd and are expected to effectively cover the length of the corridor.

2.3.3.1 Other Means of Notification

Like most buildings within the facility, the engineering building is equipped with a PA system meant for communicating information to employees. Announcements vary in urgency and type, but include anything from weather condition alerts to notifying occupants of specific hazards, etc. When a building fire alarm is received, an announcement is made alerting all personnel in the facility to stay clear of the affected building. All announcements delivered over the PA system are voiced by trained operators in the SRTE facility control room, located in a nearby building. The control room is staffed 24/7 to provide constant facility oversight. All control room personnel follow operational procedures for giving announcements and are trained in delivering emergency instruction.

Employees are also given specific training on how to respond to certain alarms and announcements as a part of the site orientation process. Given that the employees at SRS deal with numerous hazards associated with nuclear work, it is imperative that all site employees are familiar and responsive to notifications.

Wiring details for the public address system could not be located, therefore the pathway survivability for the system could not be determined. However, it can be reasonably assumed that there is no level of survivability for the PA system. The PA operates as an independent system and has no ties to the FACP.

2.3.4 Secondary Power

NFPA 72 section 10.5.6 requires enough standby power to sustain 24 hours of fire alarm system operation in a quiescent state followed by 5 minutes of operation in an alarm state under a full load. An additional 20% must also be added to the calculated power requirement to serve as a safety margin. The total power draw calculated under the conditions above was approximately 12.43 Ah. The secondary power supply for this panel is comprised of two 18 Ah batteries which is more than adequate for operating these devices in the event of power failure. The battery load calculation for the TEB is shown in Table *2-8*.

NOTE: Per specification for the 4100ES panel, the current draw for all “IDNET” addressable devices (in this case—all initiating devices) is constant. Duct detectors are an exception as they require a power for the IDNET loop in addition to regular power for constant air sampling.

Table 2-8: Battery Loading Calculation

		Standby Current per Unit, Amps		Alarm Current per Unit, Amps	
Part #	Qty	Standby Current	Total Standby	Alarm Current	Total Alarm
FACP					
4100 ES	1	0.373	0.373	0.47	0.47
Event Reporting Dact	1	0.03	0.03	0.04	0.04
Initiating Devices					
Smoke Detectors (IDNET)	3	0.0008	0.0024	0.001	0.003
Pull Stations (IDNET)	5	0.0008	0.004	0.001	0.005
Duct Detectors (IDNET)	2	0.0008	0.0016	0.001	0.002
Duct Detectors	2	0.003	0.006	0.015	0.03
Notification Appliances					
Horn/Strobe 75 cd	15	0	0	0.221	3.315
Strobe 75 cd	2	0	0	0.186	0.372
		Total Standby	0.417	Total Alarm	4.237

	Time (Hrs)	Total Current Draw (A)	Standby (Ah)
Standby Time	24	0.417	10.008
Alarm Time	0.083	4.237	0.353
Total			10.361
+ 25% Safety Factor			2.072
Total Required Standby Power			12.433

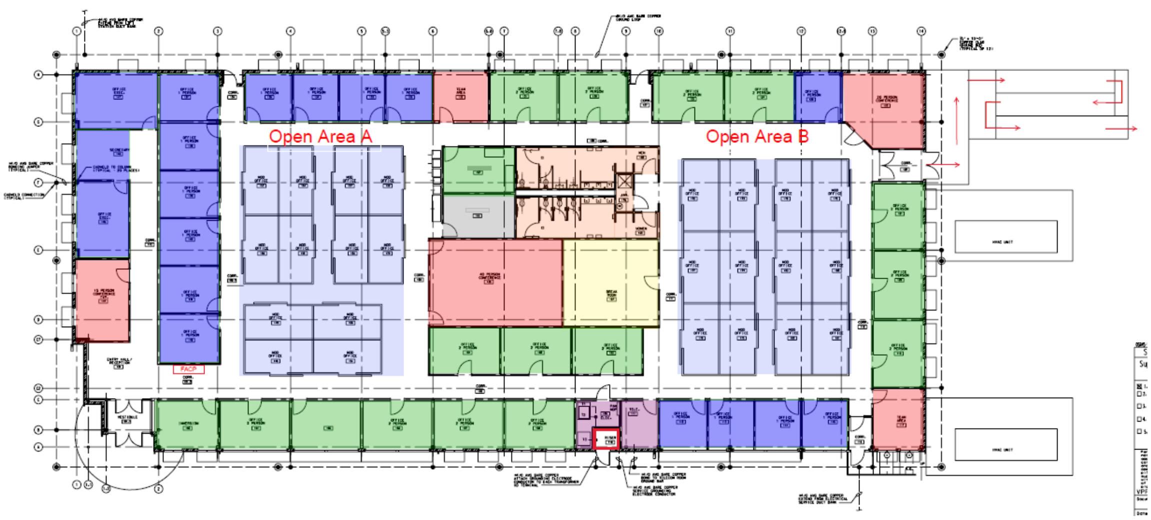
2.3.5 Alarm and Detection Summary

This section discussed the prescriptive requirements that were used in the design of the TEB fire alarm and detection system. The placement, spacing, and means of notification were evaluated and found to be within the requirements of NFPA 72. The following section will discuss the life safety features of the TEB and related egress requirements.

2.4 Egress and Life Safety

The TEB was completed and occupied in 2013 and utilized the IBC (2009) for design/construction and the LSC (2009) for life safety analysis. Since SRS requires compliance with the most recent edition of the LSC, the analysis in this section will use the 2018 edition. The LSC splits the requirements for business occupancies into two categories; new and existing. This analysis will examine the TEB as an existing business occupancy as discussed in the LSC Chapter 39. In some areas, determinations out of the IBC (2018) will be made for comparison.

Although the entire building is considered a business occupancy, the uses of the rooms/spaces is an important consideration when determining an appropriate load factor. As indicated on the building drawings, certain rooms show designed occupant loads. These notes indicate that the collaboration/conference spaces in the building were designed for use by under 50 people and therefore do not qualify as “assembly spaces” per the LSC section 6.1.2.1 and IBC Chapter 303. Even though the intended occupant load for these rooms is specified on the building drawings, these spaces will still be examined under the requirements of the LSC. The use of each room/space is shown in Figure *2.16*.



	2-Person Office		Kitchen/Break Area
	1-Person Office		Collaboration/Meeting Space
	Bathrooms/Janitorial		Storage
	Modular Office (Open Area)		Electrical and Telecommunications
	Kitchen/Break Area		Exit Corridors

Figure 2.16: Color Coded Space/Use

2.4.1 Occupant Load

The total occupant load for the building was calculated using the factors found in Table 7.3.1.2 of the LSC. The LSC stipulates that spaces with occupant loads less than 50 people are not considered assembly occupancies. As shown in Table *2-9*, the "team room" and conference spaces were found to have an occupant load of less than 50 people and are designated as business occupancies.

Unlike the IBC, the LSC offers more detail for business-occupancy collaboration spaces. Table 7.3.1.2 stipulates an occupant load factor of 30 ft^2/person for collaboration spaces no more than 450 ft^2 and 15 ft^2/person for collaboration spaces greater than 450 ft^2. The "Team Rooms" would fall into the prior category as all were found to be less than or equal to 450 ft^2.

The 1 and 2-person offices indicated on the building drawings were found to be in alignment with the LSC occupancy loading calculations for business use. The break, conference, and team rooms all contain tables and chairs and are considered "less concentrated" use.

Table 2-9: TEB Occupant Load

Use/Occupancy	Occupancy	Square Footage [ft^2]	Occupancy Load Factor	Occupant Load
Team Rm. 132	Business	128	30 gross	5
Team Rm. 117	Business	147	30 gross	5
Team Rm. 123	Business	275	30 gross	10
Break Rm. 164	Business	403	15 net	27
Conf. Rm. 165	Business	562	15 net	38
Conf. Rm. 144	Business	213	15 net	15
1-Person Office (x18)	Business	Var.	150 gross	18
2-Person Office (x16)	Business	Var.	150 gross	32
Open Area A (Mod Offices)	Business	2852	150 gross	20
Open Area B (Mod Offices)	Business	2620	150 gross	18
Telephone/Elect. Rm. 109 & 111	Business	158	150 gross	2
Men/Women's Restrooms	Business	500	150 gross	4
Storage Rm. 166	Storage	153	500 gross	1
Cumulative Occupant Load				195

2.4.2 Exit Capacity

There are a total of five exit doors in the TEB as shown in Figure *2.17*. Doors B and C lead to a small grassy area abutting a security fence. This area is approximately 20 ft in width, which would provide sufficient space for occupant travel; however, it is questionable whether this area provides sufficient access to a public way as required by LSC section 7.7.1. For this reason, these doors will be omitted from the building's exit capacity calculation though they would likely still be used to evacuate the building. Door E has a small 44" clear-width stairway leading to a public way.

The two remaining exits (Doors A and D) are double doors approximately 72" in clear-width. Door D leads to a 60" wide ramp that was installed to make the building wheelchair accessible. Using the capacity factors outlined in LSC Table 7.3.3.1, (0.2 for horizontal exits/ramps and 0.3 for stairways), the "limiting egress components" were found to be Door A, Ramp D, and Stair E, as indicated in Table *2-10*. By summing the capacities for these components, the total exit capacity of the building was calculated to be approximately 806 people. Given the occupant load of the building (195 people) these doors provide adequate exit capacity.

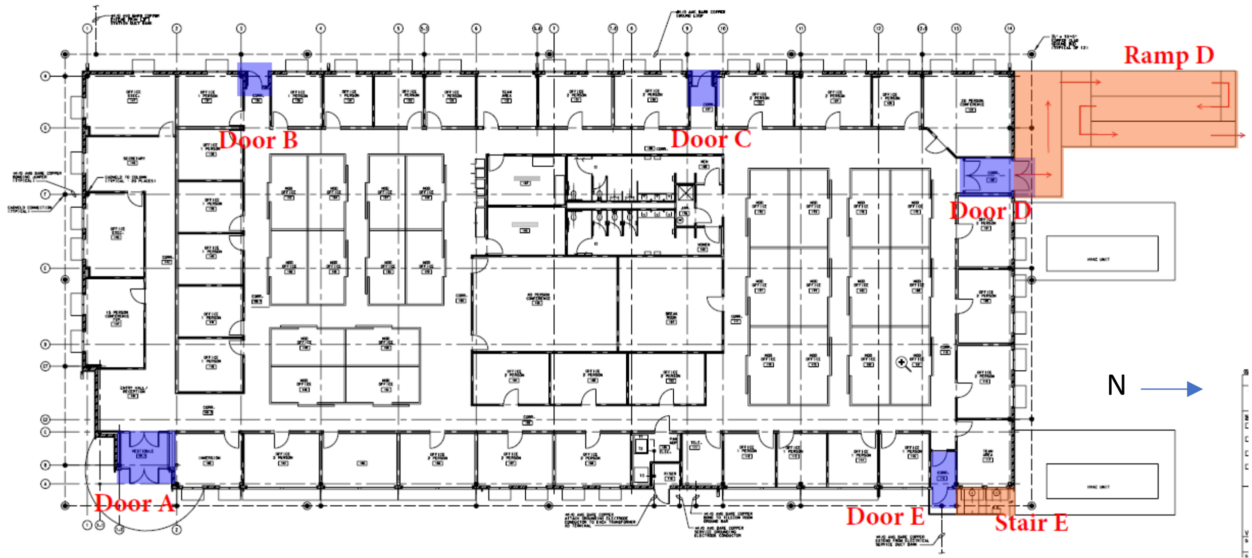


Figure 2.17: Egress Components

Table 2-10: Exit Capacity

Egress Component	Clear Width [in]	Factor [in/pp]	Egress Capacity
Door A	72"	0.2	360
Door B	34"	0.2	Not included
Door C	34"	0.2	Not included
Door D	72"	0.2	360
Ramp D	60"	0.2	300
Door E	34"	0.2	170
Stair E	44"	0.3	146
Cumulative Exit Capacity			806

*Limiting factors highlighted

2.4.3 Number of Exits

The largest gathering area in the TEB is the conference room in the center of the building. According to the building drawings, this room was designed for 40 people. The calculated occupant load (shown in Table *2-9*) is 38. Even though the space has an occupant load of less than 50 and additional doors would not be required by the IBC section 1006, this space was constructed with two exits. The LSC does not make a clear distinction of the 50-person threshold for requiring additional doors and it is assumed that the extra door was added as a conservative measure. All other interior doors in the TEB are 36” in width and provide sufficient exit capacity for their respective spaces.

As mentioned above, there are a total of five exits in the TEB—three of which are considered in this analysis. LSC section 7.4.1 requires at least three doors for an occupant load of 500 to 1000, otherwise two exits are acceptable. Given the occupant load of 195 people, the TEB has an adequate number of exits.

2.4.4 Arrangement of Exits and Dead-End Corridors

According to section 7.5.1.3.3 in the LSC, the separation distance for exits in a sprinkler-protected building shall not be less than 1/3 the length of the maximum overall dimension of the building. This requirement is clearly met for the overall building area as the northern exit (Door D) and main entry foyer (Door A) are located near opposite corners of the building (ref. Figure *2.17*). The diagonal dimension of the conference room was calculated to be approximately 35 ft and the doors are estimated to be approximately 13 ft from each other (measured from the nearest edges). This configuration meets the requirements of 7.5.1.3.3 which requires the doors to be separated by at least 10.5 ft.

Section 39.2.6.3 of the LSC stipulates that maximum travel distances shall not exceed 300 ft for business occupancies equipped with an automatic sprinkler system. The maximum travel distance was taken from inside the conference room (as shown below in Figure *2.18*) and estimated to be approximately 127 ft.

The common path of travel is restricted to a maximum of 100 ft in sprinkler-protected building as prescribed by section 39.2.5.3.1 of the LSC. This requirement applies to two spaces in the TEB; the large conference room and the lunch area. As shown in Figure *2.18*, the common path of travel does not exceed 100 ft for either of the spaces.

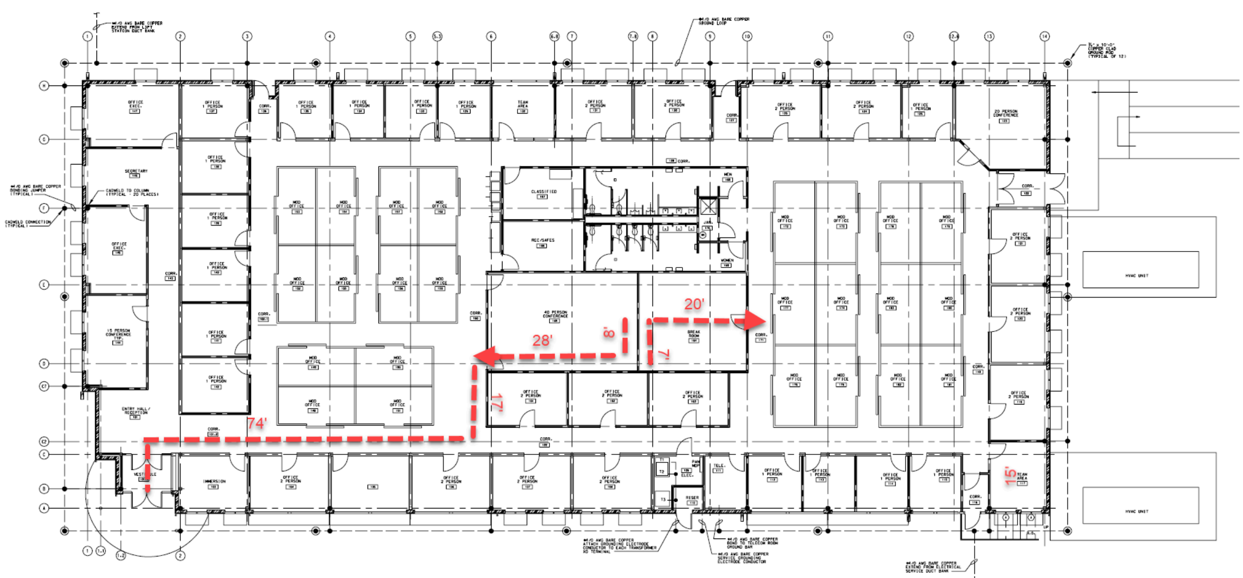


Figure 2.18: Common Path of Travel and Maximum Travel Distance

The LSC chapters for new and existing business occupancies (Ch. 38 and 39) both restrict dead-end corridors to a maximum length of 50 ft for buildings with an approved fire suppression system. The TEB was found to have one dead-end corridor that is approximately 47 ft on the south side of the building leading to the executive offices. This corridor is within the requirements of the LSC and is not usually frequented by the majority of the building's occupants. All remaining exit passageways and corridors are in accordance with section 7.5.1.1.1 of the LSC and provide access to at least two exits by separate way of travel. Corridors throughout the building were measured to be approximately 66" and comply with LSC section 39.2.3.2.

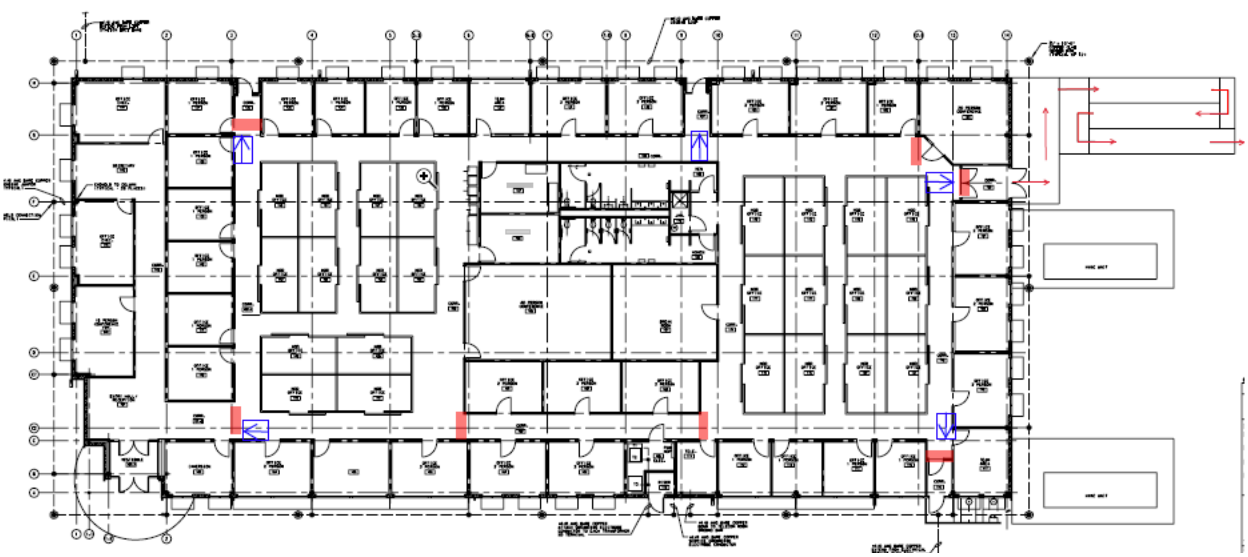
2.4.5 Exit Signage

The exit signs shown in Figure *2.19* were placed following the guidance found in LSC sections referenced below:

7.10.1.2.2—Horizontal components of the egress path within an exit enclosure shall be marked by approved exit or directional exit signs where the continuation of the egress path is not obvious.

A.7.10.1.2.2—Exit signs should be installed above doors through which the egress path leads. Directional exit signs should be installed where the horizontal egress path changes directions.

7.10.2.1—A directional sign, indicating the direction of travel, shall be placed in every location where the direction of travel to reach the nearest exit is not apparent.



*Blue Arrows Indicate Directional Exit Signs

Figure 2.19: Recommended Exit Sign Placement

2.4.6 Interior Finishes

Per section 39.3.3.2 of the LSC, interior wall and ceiling finish materials shall be at least Class A or Class B in exits and exit access corridors. Class A, B, or C finishes are allowed in all other areas. The ceiling and wall finishes in the TEB were found in the building specifications (shown in Figure *2.20*) and comply with this requirement and section 10.2 of the LSC.

INTERIOR WALL AND CEILING FINISH - PER IBC TABLE 803.9
SPRINKLERED GROUP B BUSINESS
EXIT ENCLOSURES AND PASSAGEWAYS - CLASS C (EXCEPTION B)
CORRIDORS - CLASS C
ROOMS AND ENCLOSED SPACES - CLASS C

Figure 2.20: Building Specification on Interior Finishes

2.4.7 Egress and Life Safety Summary

This analysis examined several aspects of life safety for the TEB and compared them to related codes/standards and published literature. This analysis included a summary of the building egress components, occupancy loading calculations, travel distances, and interior finish requirements for the building. Based on the analysis presented, the TEB was found to have acceptable life safety features per the 2018 version of the LSC.

2.5 Prescriptive Analysis Summary

The fire protection features of the TEB were discussed in this section and were evaluated against the governing editions of various codes and standards at the time of construction. Overall, there were no deficiencies noted as a result of this analysis and the building is in compliance with prescriptive requirements. One suggested improvement was identified and relates to adjusting the mounting height of visible notification devices in the open areas. The following section will evaluate the TEB on a performance-based basis.

3 Performance-Based Analysis

In the performance-based section of this analysis, three design fires will be described and one will be evaluated in detail against specific design objectives. The design fires are intended to provide a realistic but challenging scenario that will tax installed fire protection systems and the life safety strategy for the building. These design fires generally assume factors that contribute to a worst-case scenario. By evaluating the worst-case scenario, this analysis can be considered “bounding” and a conservative conclusion can be made for the system effectiveness against less severe fires.

3.1 Design Fire Goals and Objectives

The primary goal of fire and life safety analysis, as discussed in section 4.1 of the LSC, is to ensure that any occupant not intimate with ignition is not exposed to instantaneous or cumulative untenable conditions. All fires are required to be assessed with this primary goal in mind. In addition, performance-based design fires aim to examine at least one of five performance objectives: occupant protection, structural integrity, hazardous materials emergencies protection, physical violence mitigation, and systems effectiveness [5]. The specific objectives will be outlined and discussed in further detail for each design fire.

3.2 Required Safe Egress Time (RSET)

The required safe egress time (RSET) is the primary metric used to determine if the performance goal discussed above has been met. The RSET value is defined as the total time for all occupants to evacuate after a fire has started. It is divided into several different stages; the time for the occupants to be notified, the time for occupants to respond to the notification (pre-movement time) and the time for all occupants to exit the building (movement time).

The RSET value is compared to the available safe egress time (ASET) which is defined as the time of ignition to the onset of untenable conditions. In order to meet the primary performance goal, the RSET must be less than the ASET for occupants to evacuate safely. ASET and tenability criteria will be discussed further in later sections of this analysis. The different stages of the RSET are shown in Figure *3.1* and will be discussed in more detail within this section.

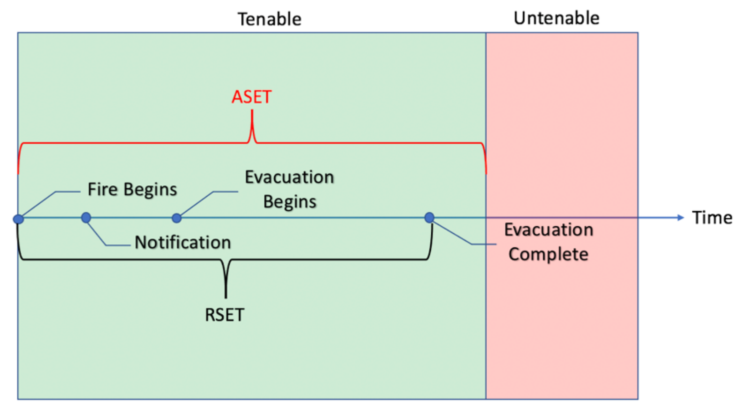


Figure 3.1: RSET vs. ASET

3.2.1 Occupancy Characteristics and Pre-Movement Times

The various characteristics of occupants plays a critical role in estimating a realistic RSET value. Many factors have been shown to influence occupant behavior during an evacuation [1]. For this reason, egress calculations should use inputs that correlate to a realistic representation of the occupants in the building. The TEB occupant characteristics will be outlined in the following paragraphs.

Ten to fifteen years ago, the occupants in the TEB were of a similar demographic—male and 30 to 60 years of age. However, with more senior engineering staff moving towards retirement, the demographic has shifted to a younger, more diverse group of individuals. Chapter 58 in the SFPE handbook details a wide array of factors that can influence human behavior in emergencies. These include the influence of stress, demographics, environmental conditions, social behavior, and culture. Currently, the TEB is estimated to have approximately 40% of its occupants above the age of 50, 35% from 30-50, and 25% under 30. The TEB occupants are estimated to be nearly 80% male and 20% female from varying backgrounds. For simplicity, this analysis will consider age as the primary influencing factor.

Most of the occupants work in the TEB daily and would be familiar with most parts of the building. This familiarity is expected to shorten the time for evacuation. The emphasis on following protocol and emergency procedures in DOE facilities is also assumed to have a positive influence on evacuation time.

Chapter 64 in the SFPE Handbook contains several tables that detail the pre-evacuation time for varied occupancies. Table 64.5, which pertains to business occupancies, will be used for this analysis. A study by Peacock, Averill, and Kuligowski [10] will be used to estimate a pre-movement time. This study evaluated the pre-movement and movement times of occupants during evacuations in multistory buildings. It was selected for use in this analysis for two reasons: It was conducted in the United States which limits any variation due to cultural norms and it examined a business occupancy with a similar occupant loading (~ 134 people). Using this data, this analysis estimates a pre-movement time of approximately 140 seconds.

3.2.2 Notification Delay

As discussed in the alarm and detection section of this report, the TEB is not fully equipped with smoke detection. For all of the design fires discussed later in this report, the flow switch at the riser is the primary means of initiating an alarm. For this initiating device, the time for the notification appliances to activate is directly related to the time it takes for the sprinkler system to activate. Depending on the properties of the fire, this could vary significantly. Since sprinkler elements depend solely on heat for activation, a significant delay is expected from the time a fire starts to the time occupants are notified. In reality, it is probable that occupants would utilize pull stations or notify other occupants prior to notification via the water flow switch. This would reduce the overall notification time. Even though this is a likely response, reliance on human behavior in emergencies is not best-practice. For conservatism, it's assumed that occupants would not use pull stations when exiting the building. For each scenario, the RSET will be evaluated based on when the sprinklers activate which will be a function of overall fire size and growth.

Table 3-1: Notification Time

T = 0	Fire occurs
T = x	Time for sprinklers to activate
T = x + 30	Time for water flow alarm to notify occupants

NFPA 72 requires an alarm signal in no more than 90 seconds. Annual surveillance documents indicate that the waterflow alarm is typically received in 10-15 seconds. Even though a 90 second activation time would be longer and thus more conservative, it's unlikely that an actual alarm would take this long. Conservatively, 30 seconds will be used in consideration of field testing. The total notification time will be calculated as shown in Table *3-1*.

3.2.3 Movement Time

For life safety analysis, the objective is to determine whether the available safe egress time (ASET) is greater than the required safe egress time (RSET). The "movement time" is the final component in calculating RSET. This time can be summed with the time to occupant notification and the pre-movement time to calculate the total evacuation time. This analysis will use the hydraulic model and computer modeling to estimate movement time of the TEB.

The hydraulic model makes three major assumptions; occupants evacuate at the same instant, occupant flow is uninterrupted (no backward flow), and most occupants are free of disabilities and otherwise unencumbered in their movement [1]. This model also ignores the effects of smoke and irritants on occupant evacuation [10] and tends toward an optimized evacuation time. For this reason, results using this model should be taken as a qualitative "modeled egress time" as opposed to a quantitative "actual egress time" [18].

During an evacuation, movement speed is largely a function of occupant density. The density for a building can be calculated by taking the total floor area (15,510 ft^2) by the anticipated occupant load (195 people). For the TEB, this calculates to approximately 0.012 people per square foot (P/ft^2).

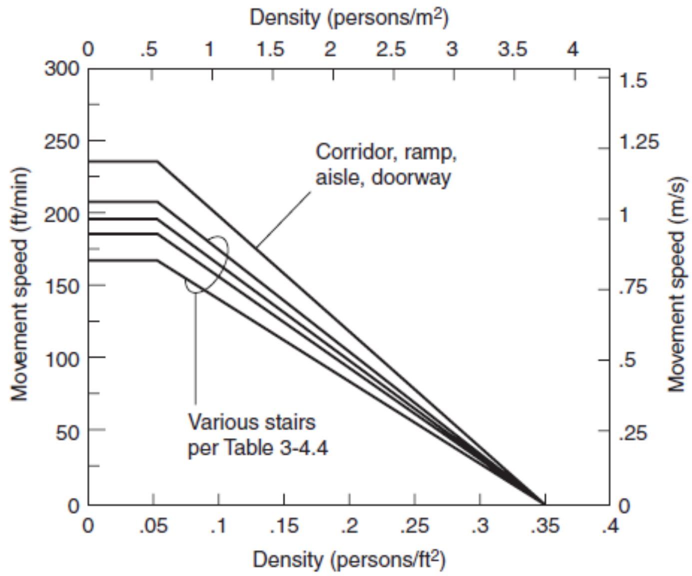


Figure 3.2: Evacuation Speed as A Function of Density [18]

As displayed in Figure *3.2*, density does not typically have an influence on movement time until approximately 0.06 P/ft^2. With the TEB density of 0.012 P/ft^2 we can assume that occupants are "free-moving" or unencumbered by those around them. Given that occupants are free moving, the approximate time for occupants to reach "point of constriction" (i.e. doors, stairwells, etc.) can be calculated by dividing a travel distance by the estimated travel speed. The points of constriction in the TEB are the "limiting factors" shown in Table *2-10*Figure *2.17* (Door A, Ramp D, and Stair E). If the time for occupants to pass through the constriction is greater than the time for the furthest occupant to reach the constriction, queuing will occur.

The maximum travel distance in the TEB, as shown in Figure *2.18*, was estimated to be approximately 127 ft. Assuming the occupant walking speed can be averaged as "adults" as shown in Table 64.14 of the SFPE Handbook, the average travel speed is 4.17 ft/s. Dividing the maximum travel distance by the average walking speed, the total time for the furthest occupant to exit was estimated to be approximately 30 seconds.

To use the hydraulic model for the TEB, several additional assumptions must be made. This analysis assumes that occupants are evenly distributed among the floor plan and use the three exits in an equal distribution. The time for the first occupant to reach the stairway will be ignored. The most constraining egress component is the TEB is the stairway (Stair E) which is assumed to have a 7" riser and 11" tread [18]. Since occupants will take the most time "passing through" this component, we can use it as the focus of our analysis.

The following equations are used to estimate the modeled evacuation time:

$$F_c = F_{s_{max}} W_e \qquad \text{Equation 3.1}$$

$$W_e = (44\ in - 12in) = 32\ in\ (2.67\text{ ft})$$

$$F_c = (18.5\text{ p/min/ft of Eff. Width})(2.67\text{ ft}) = 49\text{ P/min}$$

$$t_p = \frac{Total\ Occupant\ Load \times 33\%}{F_c} \qquad \text{Equation 3.2}$$

$$\boxed{t_p = 1.33\ min}$$

Using a maximum specific flow (Fs_{max}) of 18.5 P/min/ft of W_e and a boundary layer of 6" on either side of the stairway [18], the calculated flow (F_c) is found to be approximately 49 P/min. The time for 1/3 of the building occupants to exit using the stairway (t_p) was found to be approximately 1.33 minutes. Comparing t_p to the maximum estimated travel time, we can conclude that queuing would occur at the stairway. Because queuing occurs at the most constraining exit, the slight variance in movement times becomes less important and the modeled time for evacuation can be limited to the time it takes for occupants to exit using this stairway.

Finally, the estimated pre-movement time (140 seconds) is added to t_p to give an estimate for total evacuation time. Occupants of the TEB are assumed to fully evacuate in approximately 3.66 minutes.

3.2.4 Pathfinder Analysis

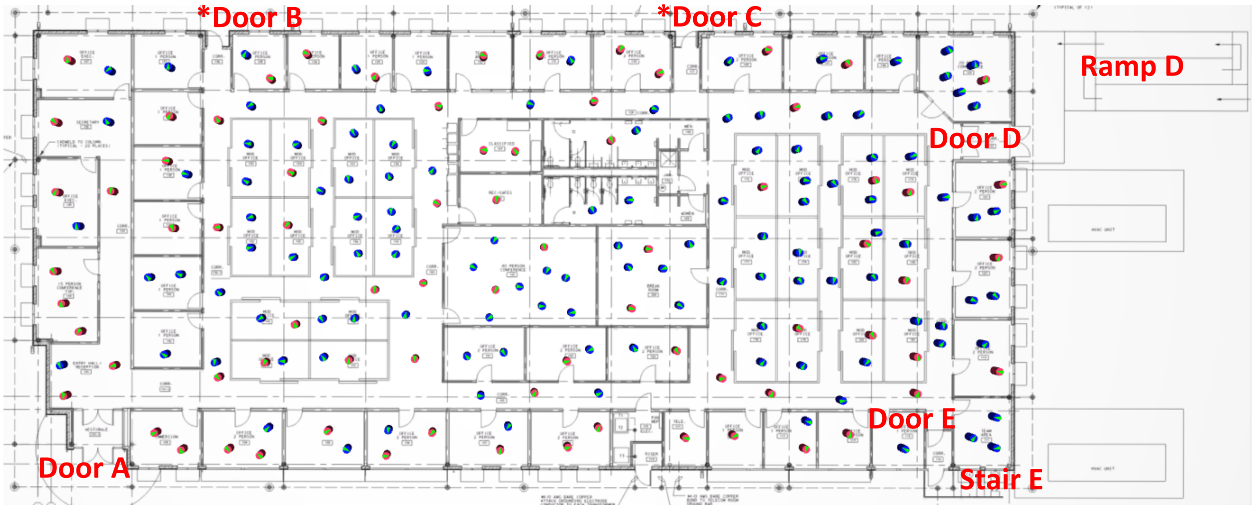
The movement time can also be modeled utilizing computer simulation programs like Pathfinder. Pathfinder allows users to specify input parameters like building geometry and occupant behavior that have a significant impact on overall evacuation time. For the purposes of modeling the evacuation of the TEB using Pathfinder, several assumptions were necessary. Referencing Table 64.14 in the SPFE Handbook, movement speeds can be assumed for the different age groups within the TEB. The selected speeds are shown in Table *3-2*.

Table 3-2: Occupant Movement Speeds

% Total Occupants	Years of Age	Movement Speed [ft/s]
40%	> 60	3.41
35%	30-60	4.17
25%	< 30	4.17

As discussed in Section 3.2.1, the majority of occupants in the TEB are considered "adults". Table 64.14 summarizes a study that separated "adults" into several different categories. The two groups that were used in this analysis were "Adults" and "Elderly". Since no distinction was made to the specific age ranges for these groups, "elderly" was considered any occupant over 60. While gender was shown to influence movement times, this factor was ignored for simplicity.

To simulate a worst-case scenario, the full occupant load of 195 was used for this simulation. Occupants of both age ranges/movement speeds were scattered at random throughout the building floor plan. The red avatars shown in Figure *3.3* represent occupants ages 60 and above and blue avatars represent occupants less than 60.



*Doors excluded from simulation

Figure 3.3: Occupant Distribution for Pathfinder Analysis

Additional assumptions were necessary for which doors are utilized during an evacuation. The west-facing doors (Doors B and C) were excluded from the modeled evacuation for a few reasons. Under normal operations, these doors are rarely used as they exit to an unpaved buffer area abutting a security fence on the west side of the building. Additionally, the "rally point" for occupants is located on the east side of the building. Occupants utilizing these exits during an evacuation would nearly double the travel distance to the rally point. The majority of occupants are assumed to use doors A and E as they provide the shortest distance to the building rally point. Further, the exclusion of doors B and C provides additional conservatism as fewer exits are available to occupants.

The default parameter of "Go To Any Exit" was used to simulate occupant behavior in an evacuation. This behavior setting directs occupants to the exit closest to them and redirects them to other exits if a shorter exit time is possible. Given the optimized nature of this behavior setting, the results from Pathfinder are likely to provide a shortened evacuation time than what would be expected in an actual evacuation scenario.

The total evacuation time for this simulation was calculated to be approximately 83.7 seconds with an average occupant evacuation time of 42.9 seconds. The number of occupants and average flow rates for each door are shown in Table *3-3*.

Table 3-3: Pathfinder Exit Utilization and Flow Rates

Egress Component(s)	Number of Occupants Utilizing Exit	Flow Rate [pers/s]
Door A	121 people	1.93
Door/Ramp D	20 people	0.79
Door/Stair E	54 people	1.00

The results from the Pathfinder simulation can be validated by comparison to the evacuation time calculated using the hydraulic model which estimated that occupants fully evacuate in approximately 79.8 seconds. Since both models have underlying assumptions that optimize evacuation times, it is reasonable to expect that they would provide similar results. Given that queuing occurs, as shown in Figure *3.4*, the total evacuation time for both methods is dependent on the time it takes occupants to move through the points of constriction.

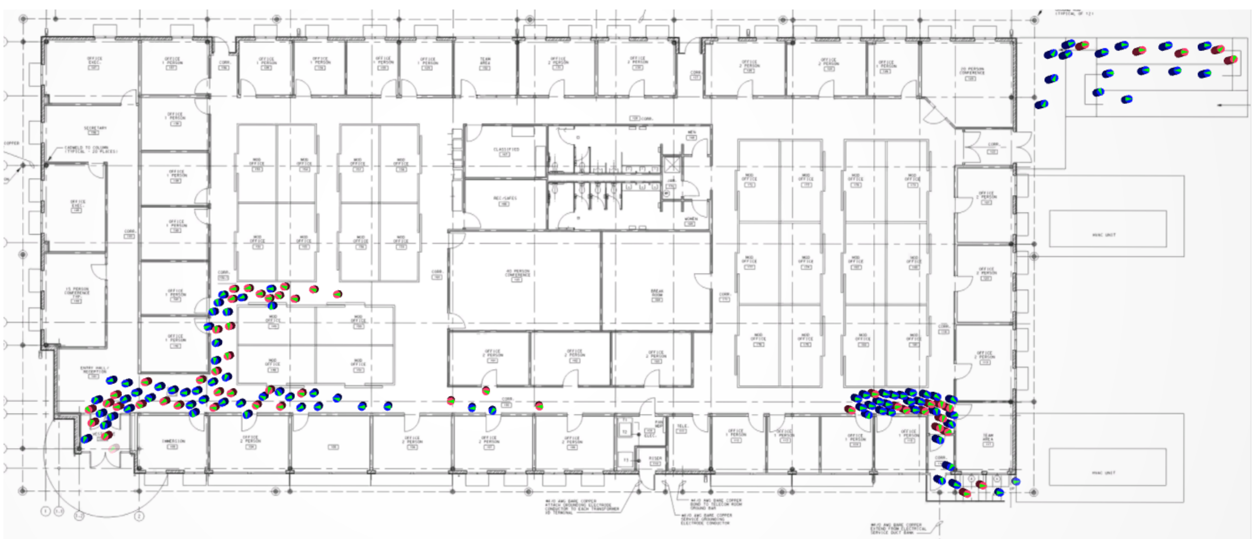


Figure 3.4: Queuing at Doors A and E at 30 seconds into Simulation

Using the results from the hydraulic model and pathfinder, an estimated value of 80 seconds will be used as the movement time in this analysis. Adding this time to the sprinkler activation time, notification time, and pre-movement time results in the total RSET value. Since sprinkler activation will be evaluated as a function of fire size and the corresponding HRR, the final RSET value will be calculated in later subsections of this analysis.

3.3 Tenability Criteria

The performance criteria outlined in Chapter 5 of the LSC stipulates that occupants who are not intimate with ignition shall not be exposed to untenable conditions (instantaneous or cumulative). This implies that occupants outside of the fire room of origin should be guaranteed safety.

Evaluating the time to the onset of untenable conditions is one way of estimating whether occupants can evacuate safely. There are primarily two factors that can contribute to incapacitation and/or death in a fire—heat exposure and smoke inhalation. As discussed in Chapter 63 of the SPFE handbook, smoke inhalation is the primary cause of fire-related fatalities. The fire plume is comprised of residual fuel and various hot gases. The irritants, asphyxiants, or toxins in the plume is largely dependent on the material that is burning. The increased use of plastics and other synthetic materials have significantly increased the amounts of asphyxiants like CO and HCN in fires. In order to determine when an untenable concentration of these chemicals occur, the concentration of smoke and levels of irritants, asphyxiants, and toxins within the plume must be determined with respect to time.

The criteria used to define untenable conditions are typically limited to temperature and the incapacitating effects caused by smoke. Smoke layer development can be categorized into two phases. The first phase encompasses the time it takes for the smoke layer to descend to the level that occupants inhabit (typically 6 ft [18]). Smoke layer descent can be modeled using a computer program or by an empirical approach using the two-zone model. The second phase begins once occupants are within the smoke layer. Optimally, occupants would evacuate prior to the smoke layer reaching the occupant level. In cases where the smoke level has descended to the occupant level, toxicity of the smoke must be evaluated.

To estimate the respective level of these toxins within the smoke once the second phase is reached, an appropriate design fire scenario must be selected. Among other variables, design fires should specify the material composition of the items that ignite. Using values found in Table A.39 of the SFPE Handbook and the corresponding heat of combustion for the material burned, mass production rates can be correlated to the HRR of the fire and numerically modeled using the equation below:

$$\dot{m}_s = y_s \frac{\dot{Q}}{\Delta \mathrm{H}_c} \qquad \text{Equation 3.3}$$

Further estimations can be obtained through computer modeling (CFAST, FDS) where concentrations can be determined based on user-defined parameters.

Typically, CO is examined as one of the primary asphyxiants that has a negative biological impact on occupants. Carboxyhemoglobin (COHb), which is produced as occupants inhale concentrations of CO, has been the focus of several studies that examined blood saturation levels corresponding to incapacitation and eventual death [13-17]. Although exceptions to these ranges exist, incapacitation has generally been estimated to occur at a range of 30-40% and death is estimated to occur at approximately 50% COHb [1].

When compared to these ranges, the Fractional Effective Dose (FED) model can be used to estimate the time to incapacitation and/or death of occupants in smoke. Different ventilation rates based on the activity being performed can found in Ch. 63 of the SFPE Handbook. Using a selected ventilation rate and the concentration with respect to time (resulting from modeling or the numerical solution as shown in Equation 3.3) the time to incapacitation or death can be calculated. Typically, incapacitation/death is most influenced by the presence of CO2 (which is directly proportional to an increase in ventilation rate) and the fractional dose of CO. The fraction of the incapacitating dose for CO2 (F_{ICO2}) is an alternate factor that can incapacitate occupants and must be analyzed independently. In most cases, a lethal level of CO is reached prior to significant levels of CO_2 production, and can be ignored without significant error.

The FED for incapacitation can be calculated using the equations from Chapter 63 in the SFPE handbook.

$$F_{IN} = [(F_{I_{co}} + F_{I_{CN}} + FIC)VCO_2 + F_{I_O}] \text{ or } F_{ICO2} \qquad \text{Equation 3.4}$$

$$F_{Ico} = 3.317 \times 10^{-5}[CO]^{1.036}(V)(t)/D \qquad \text{Equation 3.5}$$

$$VCO_2 = \exp\left(\frac{[CO_2]}{5}\right) \qquad \text{Equation 3.6}$$

For this analysis, the following tenability criteria will be used to define untenable conditions:

Smoke Layer Height and Carbon Monoxide: The SFPE handbook summarizes an incapacitation threshold of 30,000 to 35,000 ppm-min. For ease of modeling, this value will be used instead of utilizing the FED model. This threshold will only be evaluated at a level of approximately 6 ft above the floor given the TEB is one story and 6 ft is typically the level at which occupants inhabit [18].

Visibility: The recommended tenability criteria in Table 63.5 in the SPFE handbook will be used for this analysis. This table summarizes occupant behavior (mostly movement speeds) related to the optical density per meter (OD/m). The suggested tenability limit for small enclosures and travel distances is 5 m, as shown in Table *3-4*.

Table 3-4: Visibility and Occupant Behavior [1]

Table 63.5 Reported effects of smoke on visibility and behavior

Smoke density and irritancy OD/m (extinction coefficient)		Approximate visibility (diffuse illumination)	Reported effects
None		Unaffected	Walking speed 1.2 m/s
0.5 (1.15)	Nonirritant	2 m	Walking speed 0.3 m/s
0.2 (0.5)	Irritant	Reduced	Walking speed 0.3 m/s
0.33 (0.76)	Mixed	3 m approx.	30 % people turn back rather than enter
Suggested tenability limits for buildings with:			
Small enclosures and travel distances:		OD/m 0.2 (visibility 5 m)	
Large enclosures and travel distances:		OD/m 0.08 (visibility 10 m)	

Temperature: Exposure to heat can result in incapacitation or death in three ways: heat stroke, body surface burns, or respiratory tract burns [1]. Chapter 63 of the SFPE handbook discusses the relationship of temperature to human tolerance which is summarized in Figure 3.5.

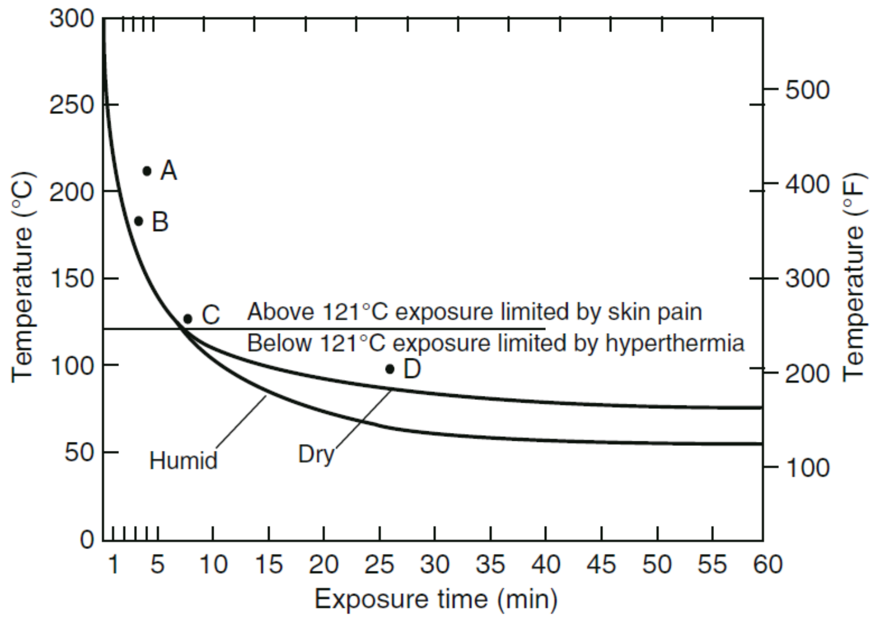


Figure 3.5: Human Tolerance to Convected Heat [1]

The maximum exposure time to a certain temperature is designated by the curve in this graph. The exposure time at a given temperature is considered to be the tenability limit. For this analysis, using Figure *3.5*, exposure to 120° C for approximately 7 minutes is considered untenable.

The tenability criteria established in this section can be used to evaluate the following design fires. Once these limits have been reached, this analysis will assume that the TEB is no longer tenable and occupant incapacitation or death would occur.

3.4 Design Fires

Several design fires were considered for the performance-based portion of this analysis. This section briefly details two design fires that may be considered for future analysis. A full analysis is provided for the third design fire which utilized Pyrosim/FDS to model and analyze the fire.

3.4.1 Design Fire I: Egress Analysis of Conference Room Fire

This design fire examines a fire in the south conference room, indicated in Figure *3.6*. The design objective for this design fire is occupant protection. NFPA 101, section 4.2.1 stipulates, “A structure shall be designed, constructed, and maintained to protect occupants who are not intimate with the initial fire development for the time needed to evacuate, relocate, or defend in place."

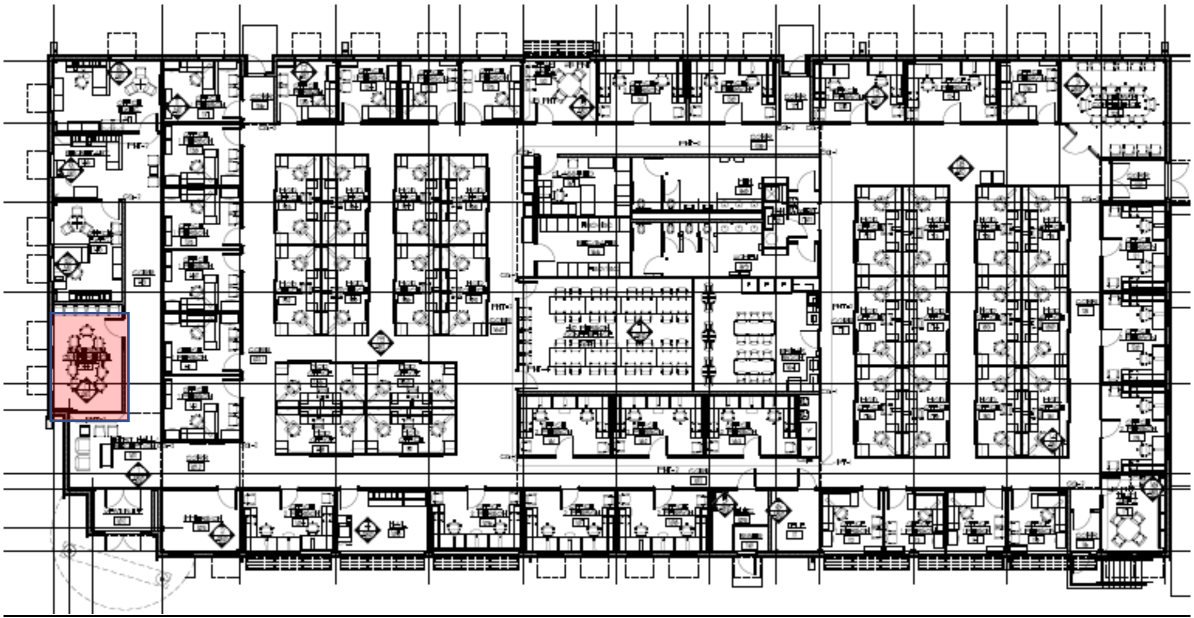


Figure 3.6: Design Fire I Location (Conference Room)

This conference room, shown in Figure *3.7*, is furnished with a large conference table, a 48" TV monitor, varied electrical equipment, and approximately 18 polyurethane chairs. This design fire assumes that the large TV monitor ignites due to an electrical failure and ignites nearby office chairs around the conference table.

Figure 3.7: Conference Room Layout

This design fire location was selected primarily for its proximity to the main entry/exit point for the TEB, as shown in Figure *3.8*. A fire in this location would ultimately impede egress and delay the overall evacuation time. While flame spread is equally probable to impede egress after a certain amount of time, this design fire would focus on selected tenability criteria to determine whether or not occupants could safely pass through the exits.

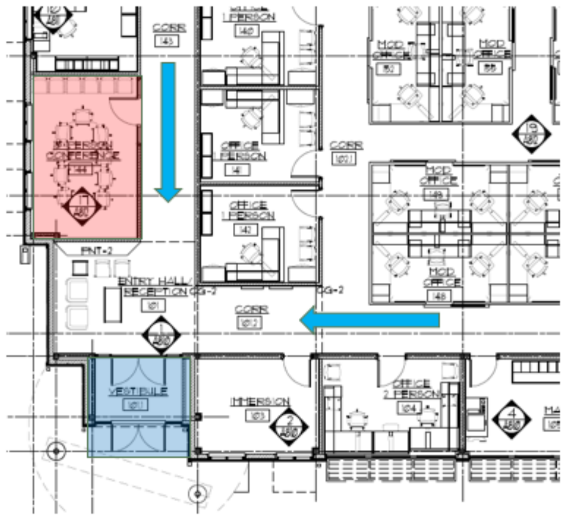


Figure 3.8: Egress paths and main entry/exit doorway

3.4.2 Design Fire II: Break Room Fire

This design fire evaluates a fire in the break room located in the center of the building, indicated in Figure *3.9*. The break room was selected as a design fire location primarily because of its small compartment size and higher quantity of ignition sources (toasters, coffee makers, microwaves, etc.). The high usage of this area is also assumed to increase the probability that an ignition incident may occur. The furnishings in this area include a TV monitor, several polyethylene chairs, and wood-type tables.

The purpose of this analysis is to determine the system effectiveness of the fire suppression system. NFPA 101, section 4.2.1 stipulates, “Systems utilized to achieve the goals of section 4.1 shall be effective in mitigating the hazard or condition for which they are being used, shall be reliable, shall be maintained to the level at which they were designed to operate, and shall remain operational.” Several of the aspects of this objective revolve around proper maintenance and reliability of the system. Maintenance is an operations function and is largely dependent on the competence of technicians. Reliability of the system can be reasonably assumed through use of listed components and the execution of approved practices during installation. Operability of the system is dependent on the proper orientation of all system control valves and an adequate water supply. The fire suppression system for the TEB was designed and installed under the guidance of NFPA 13 and is maintained in accordance with the requirements of NFPA 25 by NICET qualified technicians. For the purpose of this analysis, the aspects of reliability, operability, and maintenance are assumed to be adequate.

The primary purpose for fire suppression systems is to limit fire growth and prevent flashover. If well-ventilated, the smaller compartment size and high fuel loading of the break room leaves it susceptible to flashover. This analysis will evaluate whether or not the compartment reaches flashover prior to activation of the sprinkler system as a means of proving the system's effectiveness.

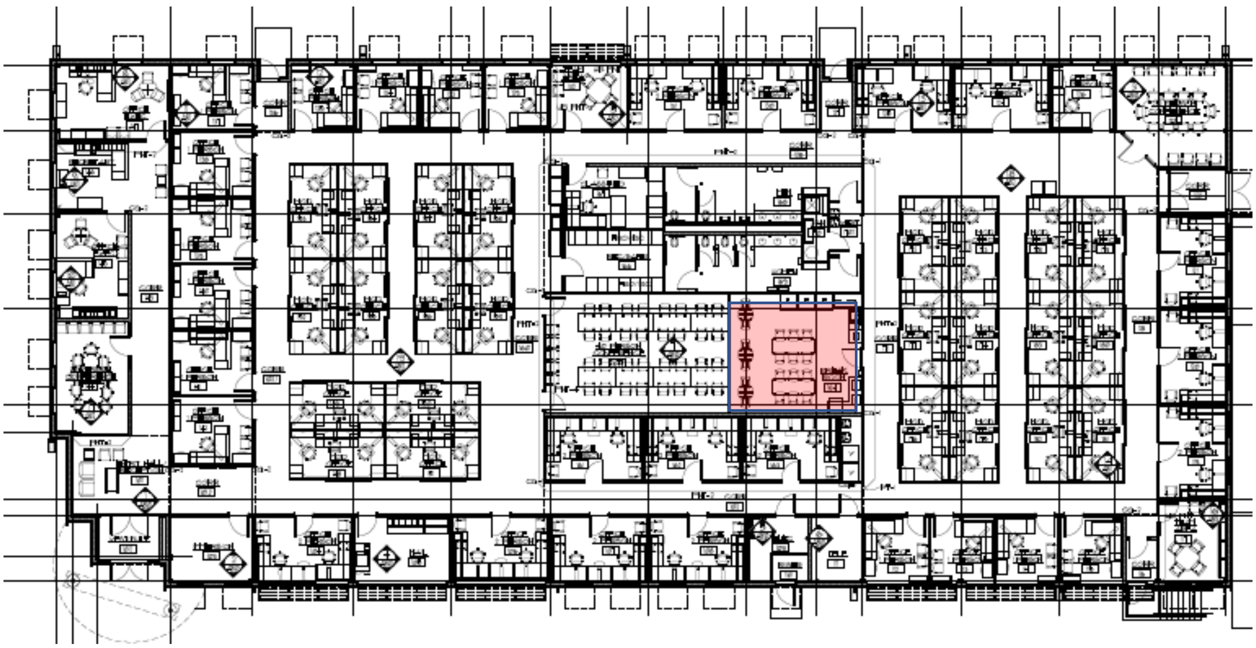


Figure 3.9: Design Fire II Location (Break Room)

3.4.3 Design Fire III: Workstation Fire in Open Area A

This design fire examines a workstation fire that takes place in Open Area A, indicated in Figure *3.10*. Two design objectives were considered for this design fire. The first evaluated whether occupants could safely evacuate prior to the onset of untenable conditions. In this portion of the analysis, RSET was compared to ASET to determine if occupants could safely evacuate.

The second objective was to evaluate the structural integrity of the building's roof support structure after prolonged fire exposure. This structural evaluation was more in consideration for firefighting personnel who may be at risk when responding to a fire in this building. NFPA 101, section 4.2.2 stipulates, "Structural integrity shall be maintained for the time needed to evacuate, relocate, or defend in place occupants who are not intimate with the initial fire development." This objective is intended for ensuring the safety of the building occupants however, the likelihood of structure failure resulting from a typical office fire is relatively low—especially within the evaluated RSET time. This analysis will provide an estimated time to failure of the supporting structural members which can be used in determining whether it is safe for firefighters to enter the building during fire response.

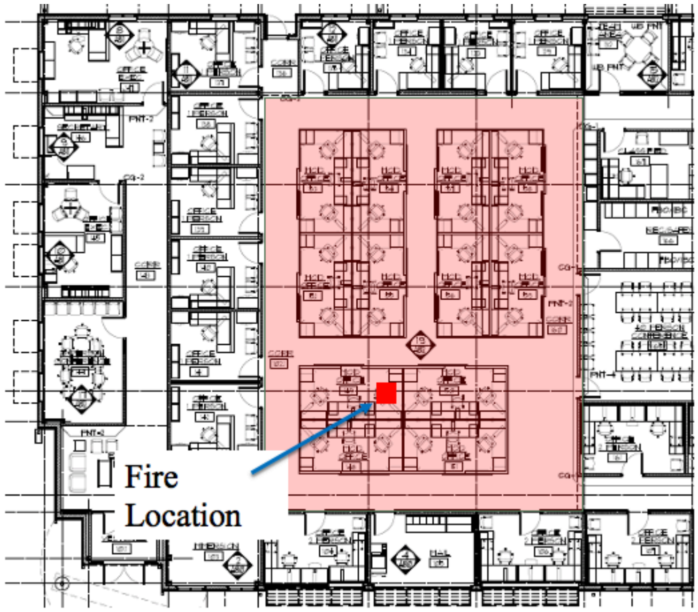


Figure 3.10: Design Fire III Location (Open Area A)

3.4.3.1 Methodology

This design fire models a fire that begins in a single a workstation, similar to the one shown in Figure *3.11*. This fire is modeled to grow until the activation of the sprinkler system. Once the sprinkler system has activated it will be assumed to “control” the fire until burnout.

Figure 3.11: Typical Workstation Configuration in the TEB “open areas”

This design fire will utilize HRR data taken from a NIST study that used oxygen consumption calorimetry to evaluate the burning of a single office workstation. This study tested two arrangements of workstations—both equipped with an assortment of typical office supplies. Though the configuration in the TEB closely resembles the four-workstation configuration, the methodology and configuration of this test did not align with the modeled fire for Open Area A. Additionally, given the presence of a fire suppression system, the fire is not anticipated to grow past a single workstation. The data selected for this analysis is shown in Figure *3.12*.

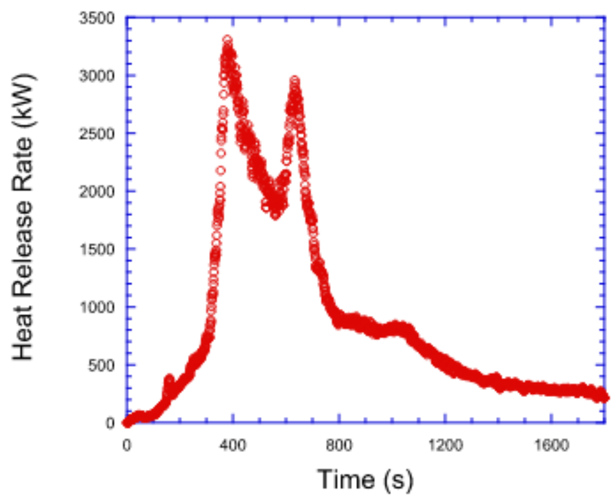


Figure 71. Single workstation heat release rate versus time

Figure 3.12: HRR Data for Workstation Fires [22]

The growth phase of the fire was modeled using the t-squared correlation:

$$\dot{Q} = \alpha t^2 \qquad \text{Equation 3.7}$$

Where,

α	Fire growth coefficient
t	Time
$\dot{Q}$	Heat Release Rate (HRR)

An alpha of 0.0206 kW/s^2 was calculated by taking the peak HRR and associated time from Figure *3.12*. Per Annex B in NFPA 72, this growth coefficient is considered to represent a medium-fast growing fire. Once the peak HRR was met, this value was maintained until the NIST HRR showed steady rate of decay. In all phases of the fire, the maximum HRR is assumed for this model. The modeled HRR is shown in Figure *3.13*.

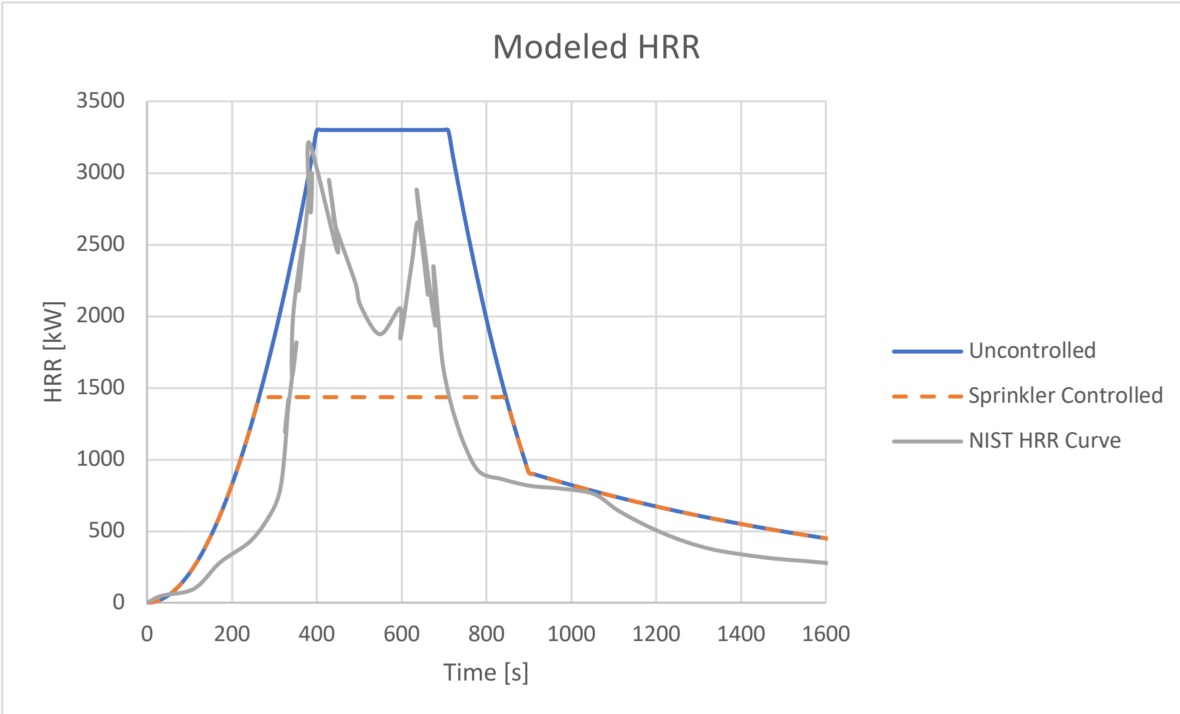


Figure 3.13: Modeled Heat Release Rate Curve

The DETACT model and Alpert's correlations were used to estimate the time for the first sprinkler to activate. Alpert's correlations (Equations 3.8—3.11) can be used to estimate the temperature and velocity the ceiling jet. These correlations assume a flat and unobstructed ceiling. Since the ceiling of the TEB slopes upward to a peak, a uniform ceiling height of 23 ft will be used. This is expected to result in a slower sprinkler activation time.

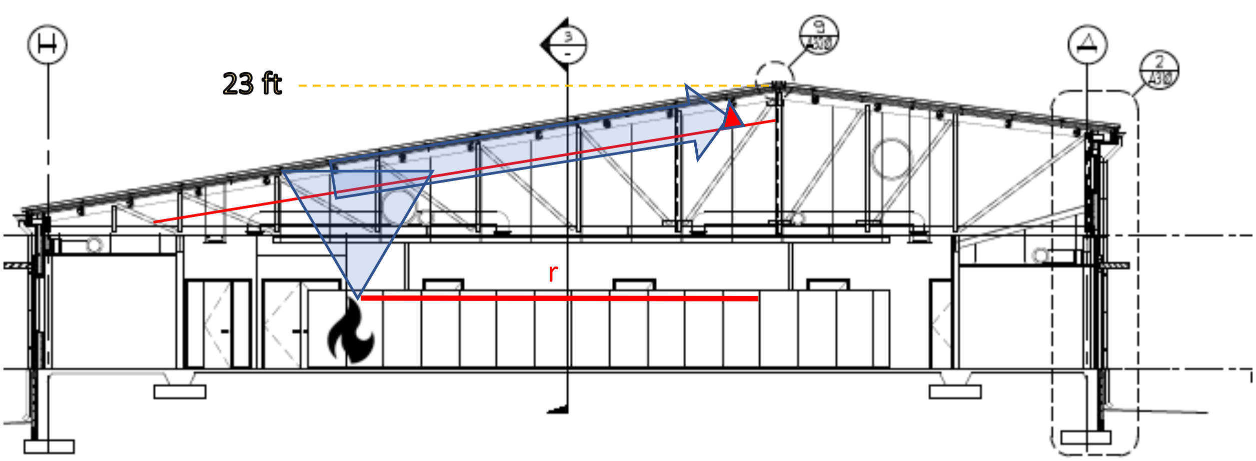


Figure 3.14: Sprinkler Piping Arrangement with Smoke Plume Movement

In reality, the buoyancy of the hot gasses would likely draw the plume upward following the slope of the roof, as indicated in Figure *3.14*. This is assumed to accelerate the velocity of the ceiling jet and shorten the time for sprinkler activation—primarily for the sprinkler heads located up the slope of the ceiling.

By assuming a uniform height of 23 ft, sprinkler activation is also assumed to be slowed due to air entrainment. The amount of air entrained into the plume is directly proportional to the height of the ceiling. As more cool air is entrained, the temperature of the plume decreases. Stratification of the smoke can also be a factor with high ceilings however, this effect was not considered in this analysis.

$$T_g - T_\infty = 16.9\frac{\dot{Q}^{2/3}}{H^{5/3}}\ for\ \frac{r}{H} \leq 0.18 \qquad \text{Equation 3.8}$$

$$T_g - T_\infty = 5.38\ \frac{\dot{Q}^{2/3}/H^{5/3}}{(r/H)^{2/3}} for\ \frac{r}{H} > 0.18 \qquad \text{Equation 3.9}$$

$$U_g = 0.947\left(\frac{\dot{Q}}{H}\right)^{1/3} for\ \ \frac{r}{H} \leq 0.15 \qquad \text{Equation 3.10}$$

$$U_g = 0.197\left(\frac{(\dot{Q}/H)^{\frac{1}{3}}}{(r/H)^{\frac{5}{6}}}\right)\ \ \frac{r}{H} > 0.15 \qquad \text{Equation 3.11}$$

Where,

$\dot{Q}$	Heat Release Rate
T_g	Temperature of ceiling jet
T_∞	Ambient temperature
U_g	Velocity of ceiling Jet
r	Distance from plume centerline
H	Height of ceiling

The DETACT model was used conjunction with Alpert's correlations to determine the temperature of the sprinkler heads (T_d) as a function of time.

$$Td^{i+1} = \frac{\sqrt{Ug}}{RTI}\left(Tg^i + Td^i\right)\Delta t + Td^i \qquad \text{Equation 3.12}$$

The extended coverage sprinklers over Open Area A have an activation temperature of 155° F and are considered "standard response" for their installed spacing. The corresponding RTI for "standard response" sprinklers is 80 m-s ½ per NFPA 13. The assumed ambient temperature was approximately 78° F and the sprinkler of interest was assumed to be located approximately 9.28 ft away from the centerline of the plume.

Using the modeled HRR curve shown in Figure *3.13*, the first sprinkler was modeled to activate at approximately 264 seconds at a HRR of approximately 1435 kW. Adding this value to the notification time, pre-movement time, and movement time discussed in Section 3.2, the total RSET for this fire was calculated to be 514 seconds.

Given that fire suppression systems installed in accordance with NFPA 13 can reasonably be expected to control a fire, it is assumed that upon activation of the suppression system, the HRR is maintained at a constant value until the fire begins to decay or the fire department arrives with additional suppression capabilities. This sprinkler controlled HRR curve, indicated in orange in Figure *3.13* will serve as the modeled heat release rate for this design fire.

3.4.3.2 Tenability Analysis

This analysis used FDS to evaluate environmental conditions in the TEB over the course of the modeled design fire. The heat release data was normalized by dividing all points on the curve by the peak heat release rate. This provided values that could be used in specifying a RAMP function in FDS to model the HRR. The building model was generated using Pyrosim and is shown in Figure *3.15*.

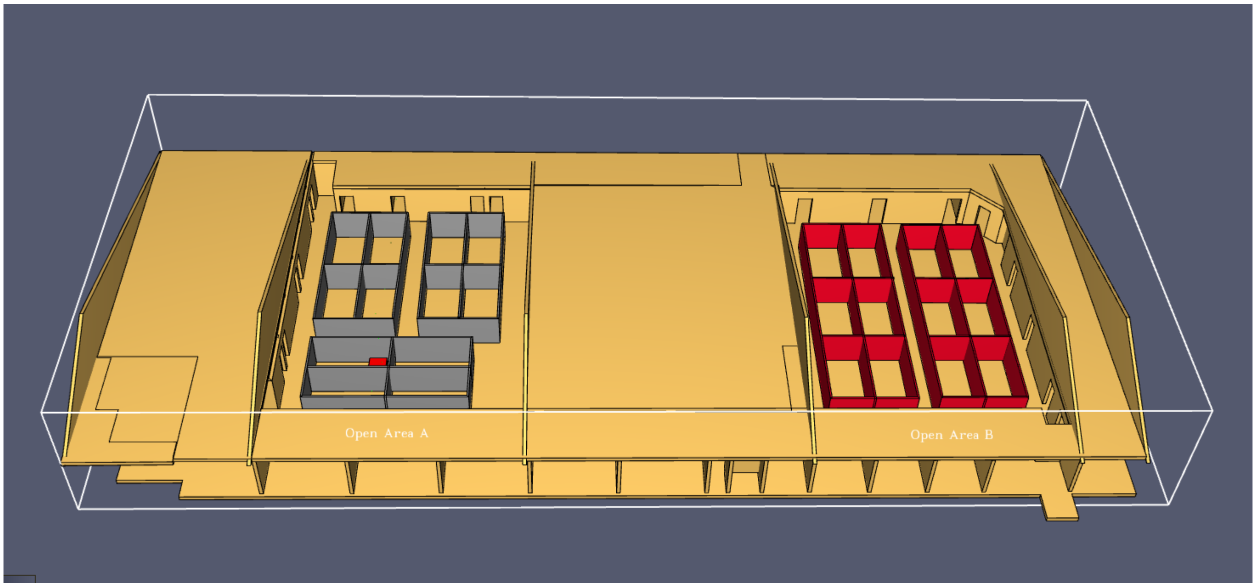


Figure 3.15: Pyrosim Model of TEB

This analysis utilized a “simple chemistry” combustion model in which users specify the chemical composition of a material, the related heat of combustion, and soot/carbon monoxide yields for the material. FDS then uses these inputs to model the combustion reaction by assuming a gas phase combustion process (pyrolysis of the material is not considered).

This analysis specified polyester as the modeled material. Polyester was selected given the significant quantity of the material used in the workstation siding. Product data for the workstations indicated that the workstation walls were composed of 100% polyester fabric. Additionally, polyester was shown to have higher combustion product yields (primarily soot yield) when compared to other materials like wood (red oak) or polyethylene. The combustion byproduct yields for polyester were taken from Table A.39 of the SFPE Handbook and are shown below:

$$\Delta H_C = 32.5\ kJ/g$$

$$y_{CO} = 0.070\ g/g$$

$$y_{Soot} = 0.091\ g/g$$

The FDS simulation was run for a duration of 1600 seconds and slice files were created to evaluated visibility, levels of carbon-monoxide, and temperature as the modeled fire burned. The results from this simulation as they pertain to the tenability criteria are discussed below.

<u>Carbon Monoxide</u>

The carbon monoxide threshold for this simulation was 30,000 ppm-min. Carbon monoxide concentration was measured at a level 6 ft above the floor and first appeared at approximately 385 seconds, as shown in Figure *3.16*.

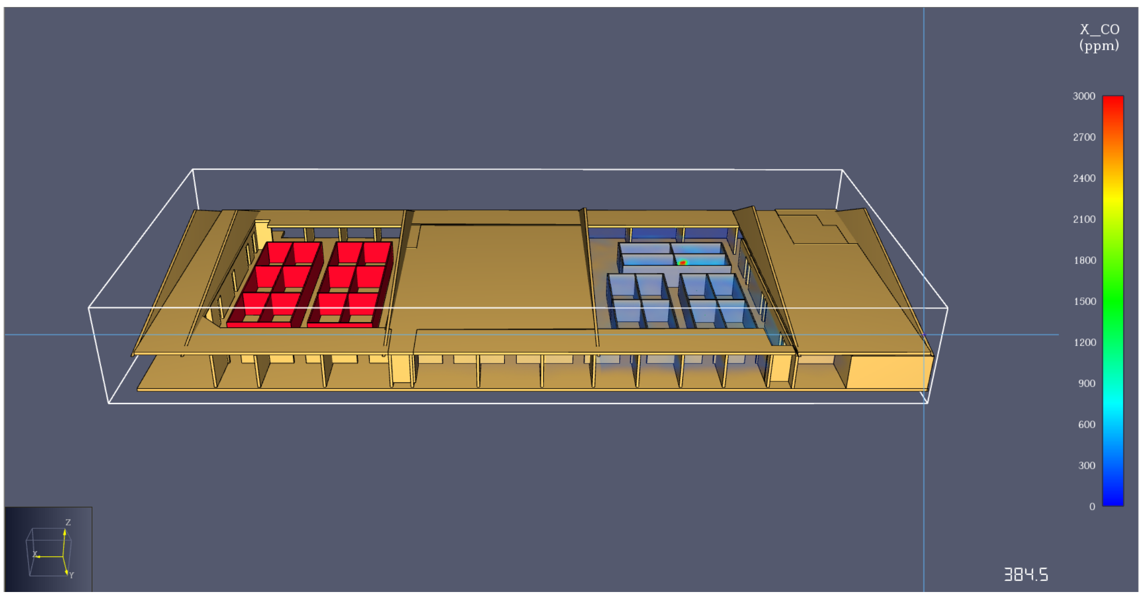


Figure 3.16: Carbon Monoxide Concentration at 6 ft A.F.F.

The carbon monoxide concentration at RSET, shown in Figure *3.17*, was observed to be approximately 600 ppm. For simplicity, this value was multiplied by RSET in minutes which resulted in a time-concentration of 5,100 ppm-min. This estimates a higher value than what would be expected given that a concentration of 600 ppm is not present for the entire duration of RSET. 5,100 ppm-min does not exceed the specified threshold of 30,000 ppm-min, therefore incapacitation due to carbon monoxide is not expected to occur. However, at this concentration, it is possible that occupants experience light headedness, dizziness, or headaches.

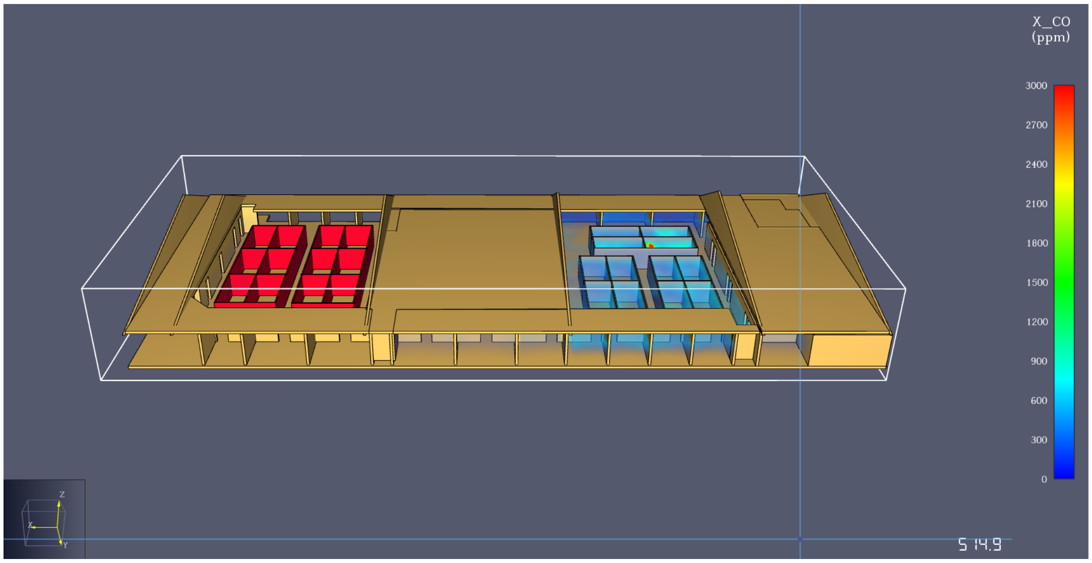


Figure 3.17: Carbon Monoxide Concentration at RSET

Temperature

Exposure to a temperature of 120° C for 7 minutes was considered untenable in this analysis. This threshold was evaluated at approximately 6 ft above finished floor.

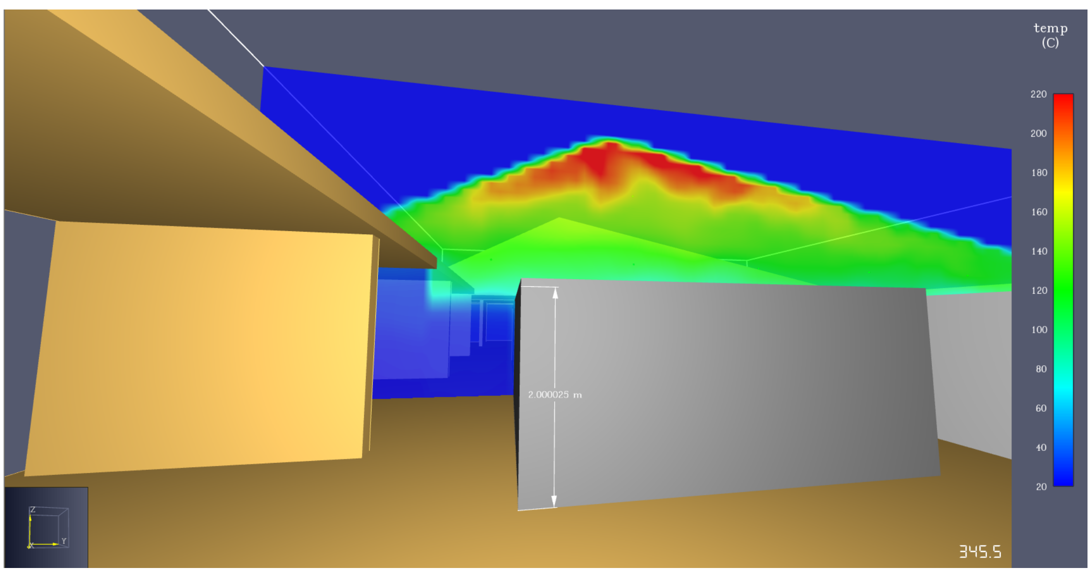


Figure 3.18: Temperature Slice File at 345 seconds

As shown in Figure *3.18*, the modeled upper layer reached a temperature of 120° C at approximately 345 seconds however, the descent of the upper layer in Open Area A was halted as the hot gases vented along the ceiling of the corridors and began filling Open Area B. As a result, the temperature threshold was never exceeded at 6 ft above finished floor.

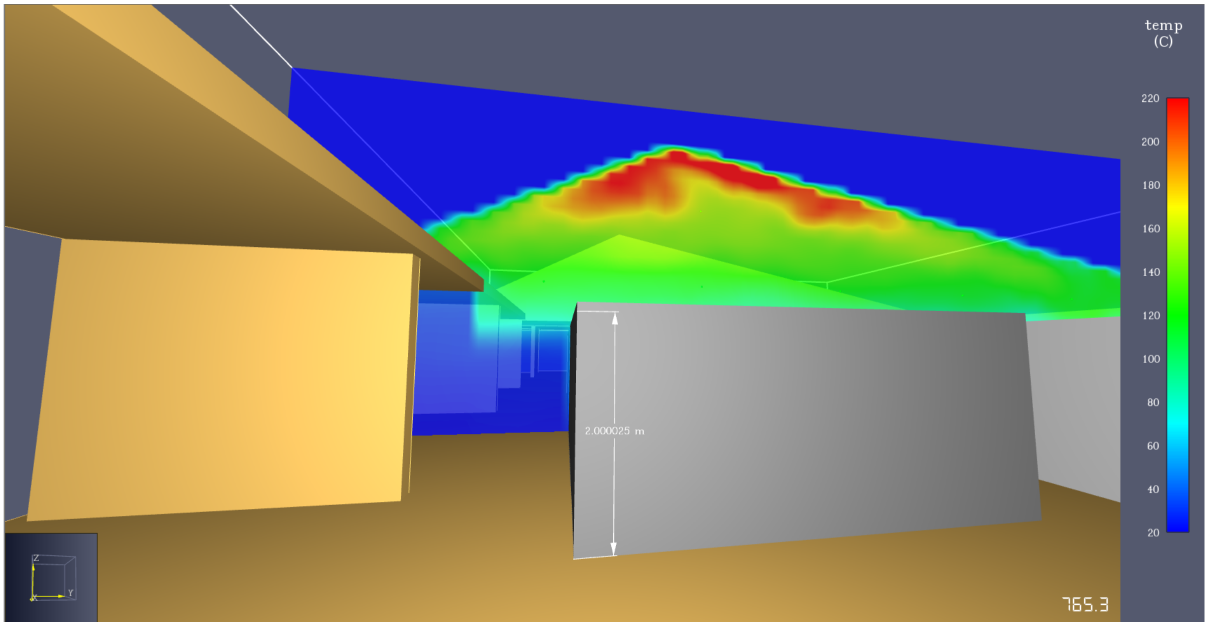


Figure 3.19: Temperature Slice File at 765 seconds (7 minutes from onset of 120° C)

Visibility

The tenability criterion for visibility as discussed in Section 3.3 was 5 m. This criterion was exceeded at approximately 215 seconds, as shown in Figure *3.20*.

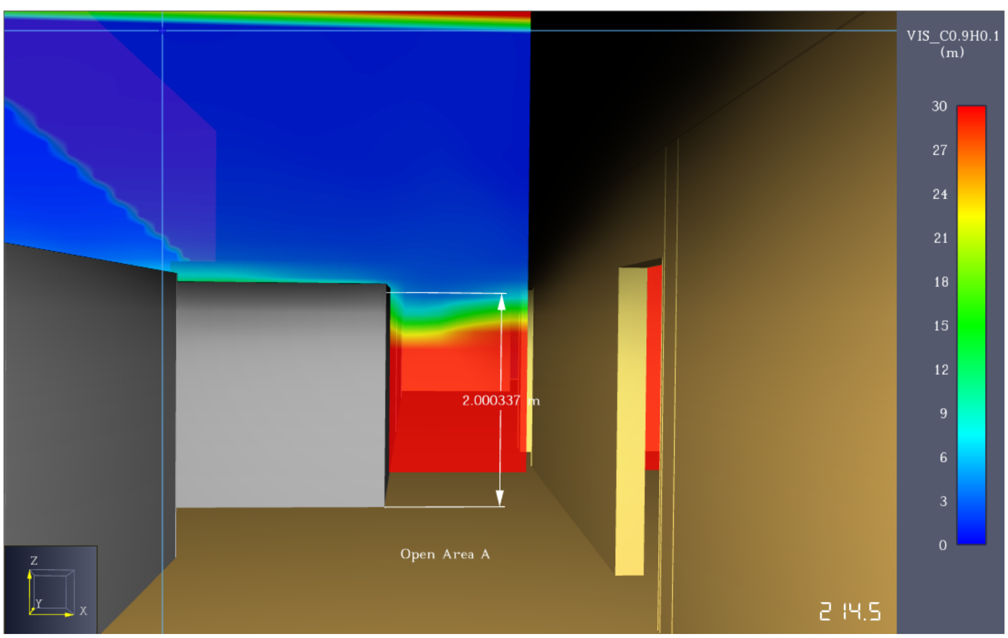


Figure 3.20: Visibility in Open Area A

With RSET estimated at approximately 514 seconds, this design fire fails to meet the design fire objective. It is likely the rapid development of smoke in the simulation can be attributed to the high soot yield specified for polyester. Additionally, given that this model assumed no ventilation (natural or mechanical), smoke was contained with no means of dispersion.

3.4.3.3 Tenability Summary

The tenability criterion for visibility was exceeded at approximately 214 seconds. The tenability criteria for carbon monoxide and temperature were not exceeded within the RSET. Given that this value is less than the calculated RSET value of 514 seconds, occupants are at risk of losing visibility during an evacuation. This could lead to disorientation and confusion during occupant evacuation which could prolong exposure to the adverse conditions created by the fire.

In reality, given the open-nature of this building, it is likely that occupants present would see or smell the smoke from a fire prior to the activation of the fire suppression system. Occupants would likely alert other occupants or utilize a pull station which would initiate the evacuation process early. This has the potential to effectively reduce the overall RSET value significantly.

3.4.3.4 Structural Analysis

This design fire also evaluated the capacity of the roof support structure after prolonged fire exposure. It is not anticipated that this supporting structure would fail during occupant evacuation. It may however, pose a hazard for responding firefighter personnel. This portion of the analysis will evaluate the loading of the beam and determine whether it is at risk of failing given the modeled temperatures at beam height.

The TEB is of Type IIB construction which indicates that the building materials are considered “non-combustible” and that structural members are not protected by fire resistive coatings. This was confirmed on a field walkdown which found exposed structural members over the building’s “open areas”. Prolonged fires in the open areas are possible given the large amount of fuel and the well-ventilated conditions in these areas. Books, paper, and combustible workstations are some examples of the various fuel packages dispersed throughout this area. The primary means of protection for these areas is the wet pipe suppression system installed along the sloped ceiling. These systems are installed primarily for property protection and are meant to prevent a total loss of the building. While it is possible for this system to extinguish a fire, a conservative assumption is that the system “controls” the fire by inhibiting additional growth. The sprinkler controlled HRR shown in Figure *3.13* reflects this by maintaining the HRR value at the time of sprinkler activation.

The beam of interest, indicated in Figure *3.21*, is located approximately 10’-8” A.F.F and is located approximately 5 ft from the center of the first cubicle. Failure of this beam is assumed to impact the integrity of the structure to the extent that is considered unsafe for firefighter entry. Based on the building specifications, the beam is W8x10 and made of A36 steel (F_y = 36 ksi, F_U = 58 ksi).

Figure 3.21: Beam of Interest in Open Area A

Due to the complex nature of calculating stresses within beams, a few critical assumptions will be made for this analysis. First, for simplicity and conservatism, this analysis will assume the beam does not have additional bracing and is "simply supported". In reality, the beam is bolted on both sides and is considered "fixed". Because of this configuration, the beam has more than three reaction forces and is considered statically indeterminate. Statically indeterminate beams have static redundancies (multiple moments) that allow forces to be re-distributed if one element fails. Calculating loads for statically indeterminate beams requires computer modeling and is not within the scope of this analysis. By assuming the beam is simply supported, a we can define a worst-case scenario since a simply supported beam does not have static redundancies and would theoretically fail before a fixed beam.

The yield strength of steel is inversely proportional to a rise in temperature. Failure occurs when the capacity of the steel beam drops below the applied loads. This can be expressed in terms of the moments experienced by the beam. The moment generated by the uniform distributed load of the roof on a simply supported beam can be calculated using Equation 3.13. The moment capacity of the beam can be modeled using Equation 3.14. If $\emptyset M_n < M_u$, failure of the beam occurs [19].

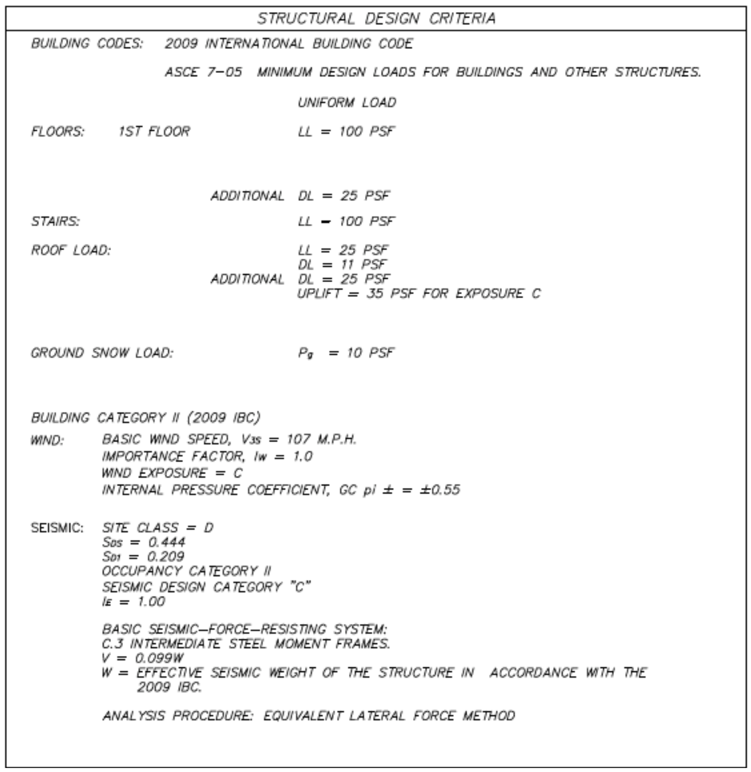
$$M_u = \frac{W_T L^2}{8} \qquad \text{Equation 3.13}$$

M_u	Applied Moment from Distributed Load
W_T	Total Distributed Load
L	Length of Beam

$$\emptyset M_n = \emptyset f_y(T) Z_x \qquad \text{Equation 3.14}$$

$\emptyset M_n$	Nominal Moment Capacity (Fire)
$\emptyset f_y(T)$	Flexural Strength at Given Temperature
Z_x	Plastic Section Modulus

The structural design criteria for the TEB is shown in Figure *3.22*. These criteria detail a live load of 25 psf and the combined dead load of approximately 36 psf.



STRUCTURAL DESIGN CRITERIA

BUILDING CODES: 2009 INTERNATIONAL BUILDING CODE

ASCE 7–05 MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES.

UNIFORM LOAD

FLOORS: 1ST FLOOR LL = 100 PSF

ADDITIONAL DL = 25 PSF

STAIRS: LL – 100 PSF

ROOF LOAD: LL = 25 PSF
DL = 11 PSF
ADDITIONAL DL = 25 PSF
UPLIFT = 35 PSF FOR EXPOSURE C

GROUND SNOW LOAD: P_g = 10 PSF

BUILDING CATEGORY II (2009 IBC)

WIND: BASIC WIND SPEED, V_{3S} = 107 M.P.H.
IMPORTANCE FACTOR, I_W = 1.0
WIND EXPOSURE = C
INTERNAL PRESSURE COEFFICIENT, GC pi ± = ±0.55

SEISMIC: SITE CLASS = D
S_{DS} = 0.444
S_{D1} = 0.209
OCCUPANCY CATEGORY II
SEISMIC DESIGN CATEGORY "C"
I_E = 1.00

BASIC SEISMIC–FORCE–RESISTING SYSTEM:
C.3 INTERMEDIATE STEEL MOMENT FRAMES.
V = 0.099W
W = EFFECTIVE SEISMIC WEIGHT OF THE STRUCTURE IN ACCORDANCE WITH THE 2009 IBC.

ANALYSIS PROCEDURE: EQUIVALENT LATERAL FORCE METHOD

Figure 3.22: Structural Design Criteria

The trusses are spaced 15’-10” from each other which suggests that the beam supports (7’11”) of roof-load on each side (ref. Figure *3.23*). The total length of the beam is approximately 83’ which results in the beam supporting a total of 1314 ft^2 of the roof. Multiplying this area by the dead and live loads, then dividing these values by the total length of the beam yields pounds per linear foot (plf) which can be taken as the distributed load on the beam. This results in a live load of 395.8 plf and a dead load of 569.9 plf.

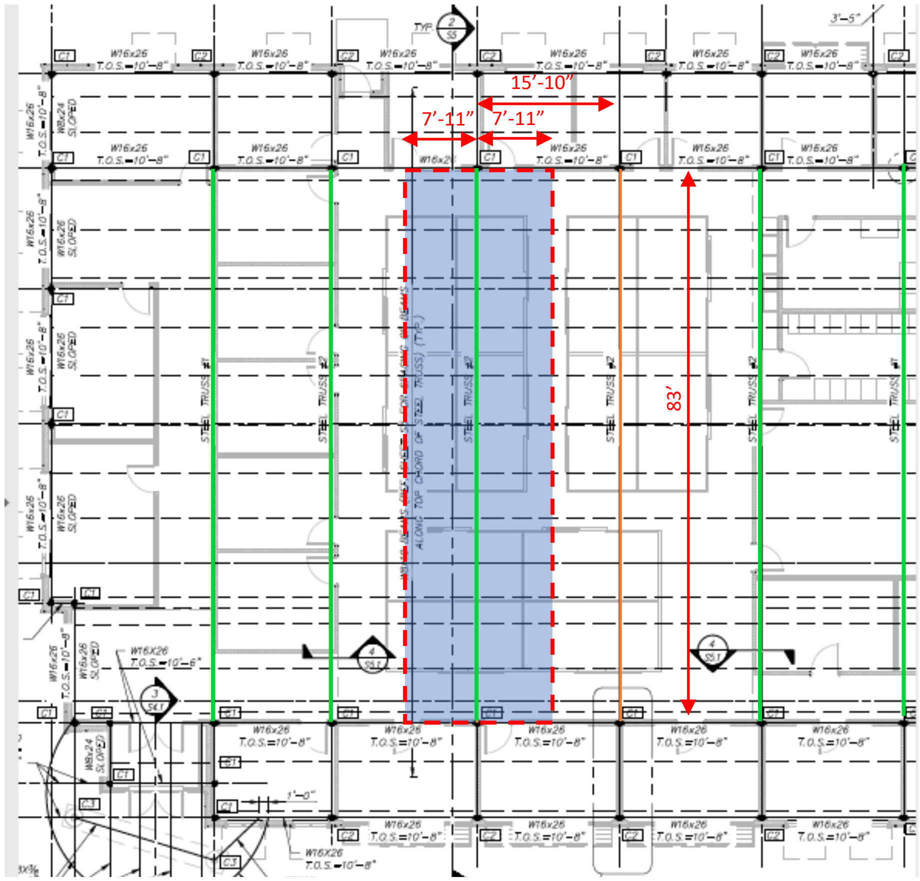


Figure 3.23: Truss Locations Relative to Workstations

Given that fire is a statistically rare event, a load combination of 1.2D + 0.5L is appropriate for this scenario [19]. Using these inputs results in a total distributed load of 881.8 plf. Using Equation 3.13 the applied moment (M_U) was calculated to be 759 k-ft.

The nominal moment capacity is a function of the yield strength (f_y) which varies with the fire growth. The yield strength can be calculated using the equation shown in Figure *3.24*.

	$0 < T \leq 600°C$	$600 < T \leq 1000°C$
Yield Strength	$\left[1.0 + \dfrac{T}{900 \ln\left(T/1750\right)}\right]\sigma_{yo}$	$\dfrac{340 - 0.34T}{T - 240}\sigma_{yo}$
Modulus of Elasticity	$\left[1.0 + \dfrac{T}{2000 \ln\left(T/1150\right)}\right]E_o$	$\dfrac{690 - 0.69T}{T - 53.5}E_o$

Figure 3.24: Yield Strength and Modulus of Elasticity for Varied Temperatures [19]

To calculate the temperature of an unprotected steel beam (T), the following correlation can be used [21]:

$$\Delta T_s = \frac{H_p}{A}\left(\frac{1}{\rho_s c_p}\right)\{h_c(T_f - T_s) + \sigma\varepsilon(T_f^4 - T_s^4)\}\Delta \mathrm{t} \qquad \text{Equation 3.15}$$

Assumed inputs:

Heated Perimeter (H_p)= 1.16 m

Cross-sectional Area of Beam = 0.0034 m^2

Convective Heat Transfer Coefficient (h_c) = 20 W/m^2K

Density of Steel (ρ_s) = 7850 kg/m^3

Stefan-Boltzmann Constant (σ) = 5.67 x 10^8 W/m^2K^4

This correlation specifies a section factor which is defined as the ratio of the heated perimeter to the cross-sectional area of the steel member (H_p/A). It also assumes that all of the heat entering the section is used to raise the temperature (simple thermodynamic model). The material properties of steel (namely specific heat, modulus of elasticity, thermal conductivity and yield strength) vary with temperature. The variance for the specific heat of steel can be modeled with the correlation shown in Figure *3.25*.

$$
\begin{aligned}
c_p &= 425 + 0.773T - 1.69\times10^{-3}T^2 + 2.22\times10^{-6}T^3 && 20^\circ C \le T \le 600^\circ C \\
&= 666 + \frac{13002}{738 - T} && 600^\circ C \le T \le 735^\circ C \\
&= 545 + \frac{17820}{T - 731} && 735^\circ C \le T \le 900^\circ C \\
&= 650 && 900^\circ C \le T \le 1200^\circ C
\end{aligned}
$$

Figure 3.25: Correlations for Specific Heat as a Function of Temperature for Steel [21]

By using these correlations to model the temperature of the steel beam, an effective yield strength can be calculated which can then be used to calculate the moment capacity for the beam as a function of time. It's important to note that these models are used for estimation purposes (given they depend on idealistic assumptions) and do not consider the cooling effects that might result from sprinkler activation.

To determine the temperature of the plume at beam height, thermocouples were placed at various distances from the centerline of the fire. These thermocouples were spaced at

4 m internals along the direction of the beam, as shown in Figure *3.26*. The measured temperatures for these thermocouples are shown in Figure *3.27*.

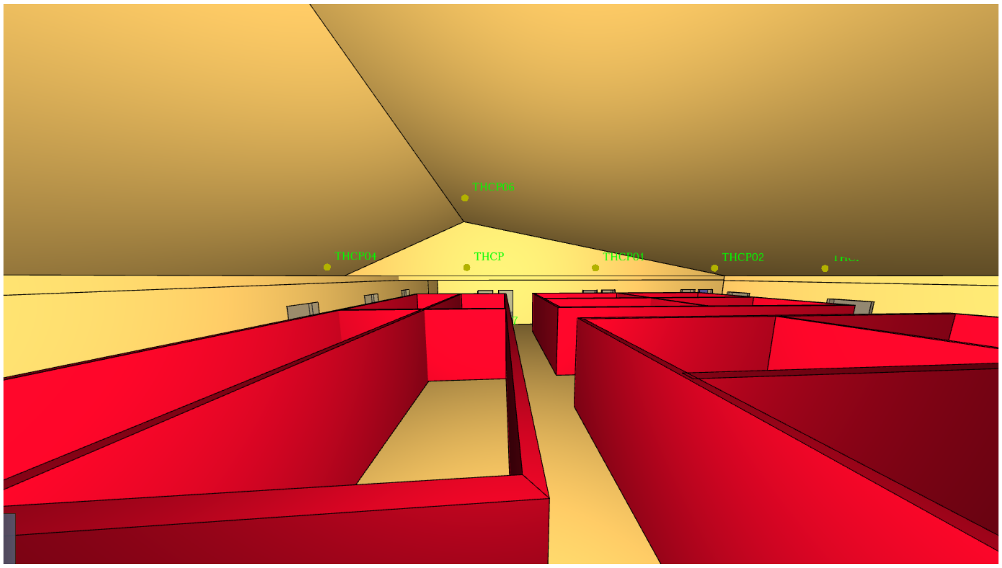


Figure 3.26: Thermocouple Locations over Open Area A

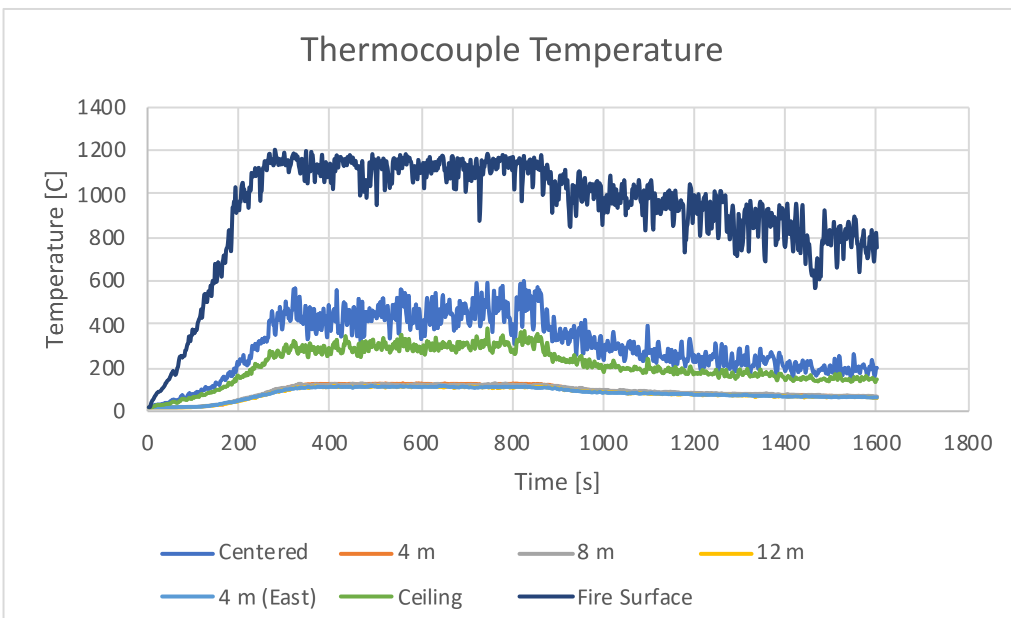


Figure 3.27: Thermocouples at 4 m Spacing Along Beam

The temperatures recorded throughout the simulation can be used with the equations above to graph the yield strength and moment capacity with respect to the HRR (ref. Figure *3.28* and Figure *3.29*).

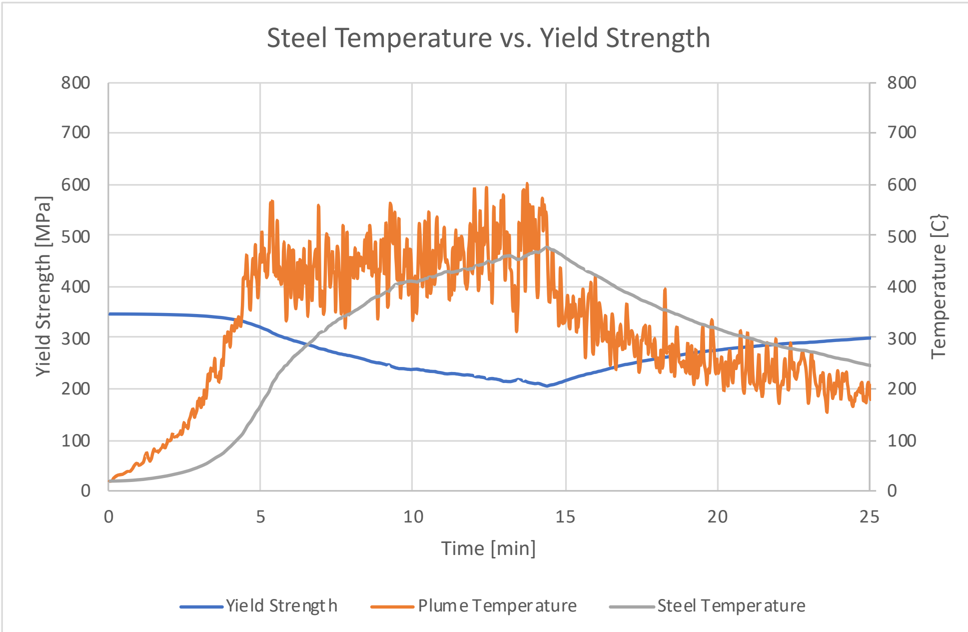


Figure 3.28: Modeled Strength of the Beam at 10.5' A.F.F.

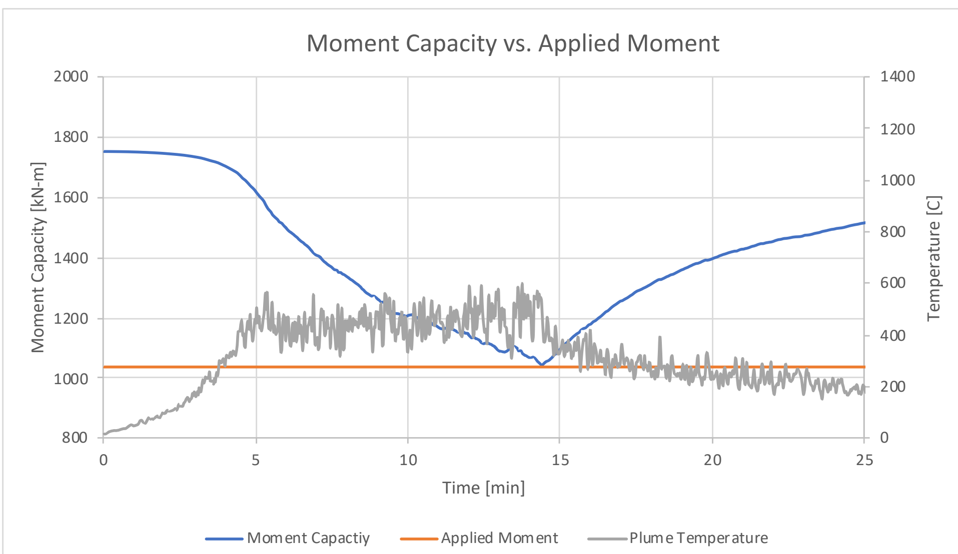


Figure 3.29: Applied Moment vs. Moment Capacity

As shown in Figure *3.29*, the moment capacity of the beam dipped to nearly meet the applied moment but did not drop below it. While this result is still a cause for concern, with additional consideration for the cooling of the beam given the fire suppression system, it can be reasonably assumed that the beam would not fail.

Structural Analysis Summary

This analysis concluded that the capacity of the beam does not drop below the applied loads for the duration of this fire. Given this conclusion, and additional considerations for the fire suppression system, the beam is not expected to fail. The fact that this beam is fixed with multiple bolts further validates that this beam would not fail due to the multiple static redundancies created by this configuration. This analysis did not consider the potential for buckling of the beam which may be possible due to the thermal expansion of the beam.

Conclusion and Recommendations

This report summarized the prescriptive requirements set forth in nationally-recognized codes and standards as they pertain to the Tritium Engineering Building (TEB) and provided a performance-based evaluation of the building's fire safety strategy.

The prescriptive portion of this report included an analysis of building construction, the automatic fire suppression system, the alarm and detection system, and life safety features/considerations. This analysis concluded that the TEB complies with nationally recognized codes and standards in these areas.

In the performance-based portion of this report, a design fire was used to evaluate various aspects of the TEB's fire safety strategy. These aspects included an evaluation of building tenability during occupant evacuation and the structural performance of the roof support structure under prolonged fire exposure.

For the evaluation of building tenability, limiting criteria were established for visibility, temperature, and carbon monoxide concentration. These criteria included a visibility limit of 5 m, maximum exposure time to 120°C for 7 minutes, and a CO concentration threshold of 30,000 ppm-min. The tenability criterion for visibility was exceeded at approximately 214 seconds, which was within the calculated RSET of 514 seconds. No other tenability criteria were exceeded within the calculated RSET. Given that RSET exceeded ASET, this analysis concluded that the TEB fails to meet the design objective of occupant safety for this design fire. This failure may be a result of the material used in computer modeling (polyester) which had a relatively high soot yield. Future modeling should evaluate several additional materials to validate this result.

The structural analysis portion of this report focused on the structural integrity of a single support beam under prolonged fire exposure. When examined under the conditions generated by the proposed design fire, the beam of interest was shown to reach a minimum yield strength of 200 MPa at approximately 14.3 minutes however, the moment capacity of the beam did not drop below the applied moment and failure did not occur.

One recommendation was identified in this analysis regarding the height of visual notification appliances. The office cubicle walls in the building's two "open areas" are slightly higher than the lens of the strobes currently mounted on the wall. While these devices are compliant with the mounting requirements detailed in NFPA 72, occupants may not be able to clearly see strobes upon activation. Slightly raising the device mounting height or installing ceiling-mounted strobes could provide a relatively low-cost solution that would ensure all occupants in the cubicle areas are capable of seeing visual notification.

Aside from this recommendation, the life safety and fire protection features were found to be acceptable. Assuming all the systems operate as designed and a fire is prevented from developing to a significant size, this analysis concludes that the TEB fire safety strategy is sufficient.

References

[1] SFPE Handbook of Fire Protection Engineering, Fifth Edition. Springer, New York, NY. 2016

[2] IBC 2009, International Building Code, International Code Council, 2009

[3] NFPA 13, 2010. *Standard for the Installation of Sprinkler Systems* and therefore. National Fire Protection Association, an International Codes and Standards Organization. Quincy, MA.

[4] NFPA 90A, 2009. *Standard for the Installation of Air-Conditioning and Ventilating Sytems*. National Fire Protection Association, an International Codes and Standards Organization. Quincy, MA.

[5] NFPA 101, 2018. *Life Safety Code.* National Fire Protection Association, an International Codes and Standards Organization. Quincy, MA.

[6] R.L. Alpert, "Calculation of Response Time of Ceiling-Mounted Fire Detectors," Fire Technology, 8, p. 181 (1972). Alperts correlations?

[7] Drysdale, Dougal (1998). "An Introduction to Fire Dynamics, Second Edition". John Wiley andSons. Retrieved 2 September 2007.

[8] "Madrzykowski, D., and Vettori, R. L., Sprinkler Fire Suppression Algorithm for the GSAEngineering Fire Assessment System (NISTIR 4833), Natl. Inst. Stand. Technol., Gaithersburg,MD (1992).

[9] Madrzykowski, D., Office Work Station Heat Release Rate Study: Full Scale vs. Bench Scale,pp. 47-55 in Interflam '96, Interscience Communications Ltd., London (1996)."

[10] Peacock RD, Averill JD, Kuligowski ED (2008) Stairwell evacuation from buildings: what we know we don't know. In: Kingsch WWF, Rogsch, Schadschneider A, Schreckenberg M (eds) Pedestrian and evacuation dynamics. ISBN 978-3-632-04503-5

[11] "Walton, W. D., and Budnick, E. K., Quick Response Sprinklers in Office Configurations: FireTest Results (NBSIR 88-3695), [U. S.] Natl. Bur. Stand., Gaithersburg, MD (1988)."

[12] B.J. McCaffery. "Some Measurements of the Radiative Power Output of Diffusion Flames."Combustion Institute: Fall Meeting of the Western States Section of the Combustion Institute,1981.

[13] R. D. Stewart, "The Effects of Carbon Monoxide on Man," Journal of Combustion Toxicology, vol. 1, pp. 167–176, 1974.

[14] R. R. Sayers and S. J. Davenport, “Review of Carbon Monoxide poisoning,” United States Government Printing Office, Washington, D.C.,
1930.

[15] D. A. Purser and W. D. Woolley, “Biological Studies of Combustion Atmospheres,” Journal of Fire Sciences, vol. 1, no. 2, pp. 118–144,
March 1983.

[16] D. A. Purser and K. R. Berrill, “Effects of Carbon Monoxide on Behavior in Monkeys in Relation to Human Fire Hazard,” Archives of
Environmental Health, vol. 38, pp. 308–315, 1983.

[17] D. A. Purser, “Chapter 4: Asphyxiant Components of Fire Effluents,” Fire Toxicity, pp. 118–198, 2010.

[18] Nelson, Harold E. and Mowrer, Frederick W., "Emergency Movement," Chapter 3-14, SFPE Handbook of Fire Protection Engineering, 3rd Edition, National Fire Protection Association, 2002, pp. 3-367 - 3-380.

[19] Emberly, Richard. “FPE 524 Structural Fire Protection—Lecture 11-12.” 20 Jul. 2020. California Polytechnical State University, San Luis Obispo.

[20] NFPA 24, Standard for the Installation of Private Fire Service Mains and their Appurtenances, 2013 Edition

[21] Emberly, Richard. “FPE 524 Structural Fire Protection—Lecture 13-14.” 27 Jul. 2020. California Polytechnical State University, San Luis Obispo.

[22] Madrzykowski, D., and Walton, W.D. Cook County Administration Building Fire, 69 West Washington, Chicago, Illinois, October 17, 2003: Heat Release Rate Experiments and FDS Simulations (NIST SP 1021), Nat. Inst. Stand. & Technol., Gaithersburg MD (2004).

Appendix A: Specification Sheets

Simplex

True*Alarm* Analog Sensing

*UL, ULC, CSFM Listed; FM Approved; MEA (NYC) Acceptance**

Addressable Duct Sensor Housings with TrueAlarm Photoelectric Sensor; Available with Multiple Relay Control

Features

Compact air duct sensor housing with clear cover to monitor for the presence of smoke**

Includes factory installed TrueAlarm photoelectric smoke sensor and features:

- Individual sensor information processed by the host control panel to determine sensor status
- Digital transmission of analog sensor values via IDNet or MAPNET II, 2-wire communications
- Programmable sensitivity, consistent accuracy, environmental compensation, status testing, and monitoring of sensor dirt accumulation

Model 4098-9755:

- Basic duct sensor housing (no relay output) powered by IDNet/MAPNET II communications

Model 4098-9756:

- Duct sensor housing with supervised output for multiple remote relays; requires separate 24 VDC; includes one relay
- Relay output is under panel control
- At the panel, relay output can be activated manually or in response to a separate alarm or other input

General features:

- UL listed to Standard 268A
- Clear cover allows visual inspection
- Test ports provide functional smoke testing access with cover in place
- Mounts to rectangular ducts or round ducts; minimum size is 8" (203 mm) square or 18" (457 mm) diameter
- Magnetic test feature for alarm initiation at housing
- Optional weatherproof enclosure is available separately (refer to data sheet S4098-0032)

Diagnostic LEDs (on interface board):

- Red Alarm/Trouble LED for sensor status and communications polling display
- Yellow LED for open or shorted trouble indication of supervised relay control (4098-9756 only)

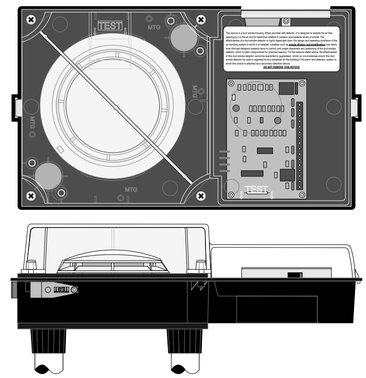
Sampling tubes (ordered separately):

- Available in multiple lengths to match duct size
- Installed and serviced with housing in place

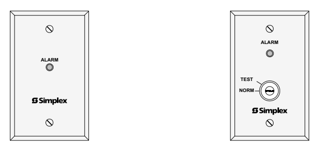
Remote module options (ordered separately):

- Remote red status/alarm LED (2098-9808)
- Remote test station with LED (2098-9806)
- 4098-9843 remote relays (refer to page 2 for details)

* These products have been approved by the California State Fire Marshal (CSFM) pursuant to Section 13144.1 of the California Health and Safety Code. See CSFM Listing 3240-0026.241 for allowable values and/or conditions concerning material presented in this document. Accepted for use – City of New York Department of Buildings – MEA35-93E. Additional listings may be applicable; contact your local Simplex product supplier for the latest status. Listings and approvals under Simplex Time Recorder Co. are the property of Tyco Fire Protection Products.



Duct Sensor Housing, Front and Bottom View



2098-9808 2098-9806

Remote Status/Alarm Indicator and Test Station

Introduction

Operation. Simplex® compact air duct smoke sensor housings provide TrueAlarm operation for the detection of smoke in air conditioning or ventilating ducts. Sampling tubes are installed into the duct allowing air to be directed to the smoke sensor mounted in the housing.

TrueAlarm Sensor Operation

Digital Communication of Analog Sensing. Analog information from the sensor is digitally communicated to the control panel where it is analyzed. Sensor input is stored and tracked as an average value with an alarm or abnormal condition being determined by comparing the sensor's present value against its average.

Intelligent Data Evaluation. Monitoring each photoelectric sensor's average value provides a software filtering process that compensates for environmental factors (dust, dirt, etc.) and component aging, providing an accurate reference for evaluating new activity. The result is a significant reduction in the probability of false or nuisance alarms caused by shifts in sensitivity, either up or down.

** Please note that smoke detection in air ducts is intended to provide notification of the presence of smoke *in the duct*. It is not intended to, and will not, replace smoke detection requirements for open areas or other non-duct applications.

Simplex

True*Alarm* Analog Sensing

*UL, ULC, CSFM Listed; FM Approved; MEA (NYC) Acceptance**

TrueAlarm Analog Sensors – Photoelectric and Heat; Standard Bases and Accessories

Features

TrueAlarm analog sensing provides:

- Digital transmission of analog sensor values via IDNet or MAPNET II two-wire communications

For use with the following Simplex® products:

- 4007ES, 4010, 4010ES, 4100ES, and 4100U Series control panels; and 4008 Series control panels with reduced feature set (refer to data sheet S4008-0001 for details)
- 4020, 4100, and 4120 Series control panels, Universal Transponders, and 2120 TrueAlarm CDTs equipped for MAPNET II operation

Fire alarm control panel provides:

- Peak value logging allowing accurate analysis of each sensor for individual sensitivity selection
- Sensitivity monitoring satisfying NFPA 72 sensitivity testing requirements; automatic individual sensor calibration check verifies sensor integrity
- Automatic environmental compensation, multi-stage alarm operation, and display of sensitivity directly in percent per foot
- Ability to display and print detailed sensor information in plain English language

Photoelectric smoke sensors provide:

- Seven levels of sensitivity from 0.2% to 3.7% (refer to additional information on page 3)

Heat sensors provide:

- Three fixed temperature sensing thresholds: 135° F, 155° F and 190° F
- Rate-of-rise temperature sensing
- Utility temperature sensing
- Listed to UL 521 and ULC-S530

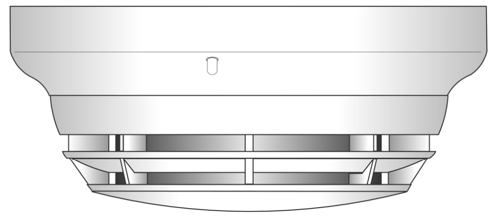
General features:

- Operation is for ceiling or wall mounting
- Listed to UL 268 and ULC-S529
- Louvered smoke sensor design enhances smoke capture by directing flow to chamber; entrance areas are minimally visible when ceiling mounted
- Designed for EMI compatibility
- Magnetic test feature is provided
- Different bases are available to support a supervised or unsupervised output relay, and/or a remote LED alarm indicator

Additional base reference:

- For isolator bases, refer to data sheet S4098-0025
- For sounder bases, refer to data sheet S4098-0028
- For photo/heat sensors, refer to data sheet S4098-0024 (single address) and S4098-0033 (dual address)

* These products have been approved by the California State Fire Marshal (CSFM) pursuant to Section 13144.1 of the California Health and Safety Code. See CSFM Listings 7272-0026:218, 7271-0026:231, 7270-0026:216, and 7300-0026:217 for allowable values and/or conditions concerning material presented in this document. Accepted for use – City of New York Department of Buildings – MEA35-93E. Additional listings may be applicable, contact your local Simplex product supplier for the latest status. Listings and approvals under Simplex Time Recorder Co. are the property of Tyco Fire Protection Products.



4098-9714 TrueAlarm Photoelectric Sensor Mounted in Base

Description

Digital Communication of Analog Sensing. TrueAlarm analog sensors provide an analog measurement digitally communicated to the host control panel using Simplex addressable communications. At the control panel, the data is analyzed and an average value is determined and stored. An alarm or other abnormal condition is determined by comparing the sensor's present value against its average value and time.

Intelligent Data Evaluation. Monitoring each sensor's average value provides a continuously shifting reference point. This software filtering process compensates for environmental factors (dust, dirt, etc.) and component aging, providing an accurate reference for evaluating new activity. With this filtering, there is a significant reduction in the probability of false or nuisance alarms caused by shifts in sensitivity, either up or down.

Control Panel Selection. Peak activity per sensor is stored to assist in evaluating specific locations. The alarm set point for each TrueAlarm sensor is determined at the host control panel, selectable as more or less sensitive as the individual application requires.

Timed/Multi-Stage Selection. Sensor alarm set points can be programmed for timed automatic sensitivity selection (such as more sensitive at night, less sensitive during day). Control panel programming can also provide multi-stage operation per sensor. For example, a 0.2% level may cause a warning to prompt investigation while a 2.5% level may initiate an alarm.

Sensor Alarm and Trouble LED Indication. Each sensor base's LED pulses to indicate communications with the panel. If the control panel determines a sensor is in alarm, or is dirty or has some other type of trouble, the details are annunciated at the control panel and that sensor base's LED will be turned on steadily. During a system alarm, the control panel will control the LEDs such that an LED indicating a trouble will return to pulsing to help identify the alarmed sensors.

Simplex

System Accessories

UL, CSFM Listed;
*MEA (NYC) Acceptance**

Fire Alarm Control Relays, Track Mount and Encapsulated; Model 4098-9843 and 2088 Series

Features

UL listed under Standard 864 as Control Unit Accessory (UOXX)

Track mount package availability:

- Single relay module or four relay module, with or without cover, with SPDT or DPDT contacts
- LED indicates relay module status
- Cover provide status LED viewing ports
- Multiple coil voltage inputs, diode polarized for DC
- Modules are track mounted with snap-apart feature design allowing the four relay module to be separated

Single encapsulated SPDT relay package with color coded 18 AWG wire leads, available in two versions:

- 2088-9021 (PAM-1) Provides diode polarized multiple input voltage ability and LED indication
- 4098-9843 (PAM-SD) Provides a diode polarized 24 VDC coil with in/out wiring

Description

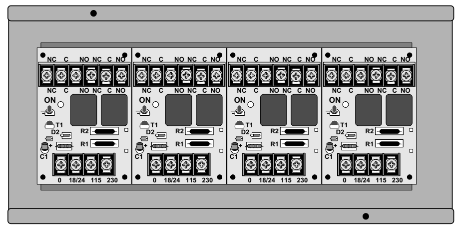
These multi-purpose control relays offer SPDT or DPDT, 10 A (or 7 A) contacts in a variety of mechanical packages. Models are available for coil operation by one of four input voltages allowing a single relay to be energized from a voltage source of 18-35 VDC or VAC, 120 VAC, or 230 VAC (not available with 4098-9843). Voltage selection is made by wiring to the appropriate input terminals or wire leads.

Each relay model (except model 4098-9843) contains a red LED which indicates that the relay is energized.

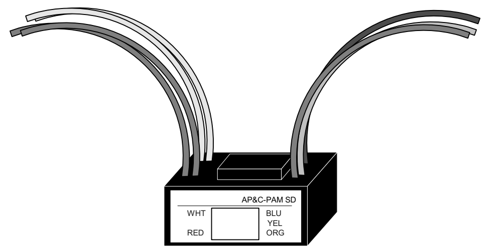
Mounting options are varied for application flexibility. Track mounted relays may be "snapped apart" from a standard four-module assembly and used independently if desired.

Specifications

Track Mount Relays, see page 2 for dimensions	
Coil Voltage	18-35 VAC/VDC, 120, or 230 VAC
Coil Current	SPDT models = 18 mA DPDT models = 40 mA
Terminal Blocks	Up to 14 AWG (2.08 mm^2)
Contact Ratings	10 A @ 120 VAC
	N.O. rated 1/6 HP, N.C. rated 1/8 HP
	7A @ 28 VDC and @ 230 VAC
Temperature Ratings	
UL Listed Range	32° F to 120° F (0° C to 49° C)
Operating Range	-58° F to 185° F (-50° C to 85° C)
Humidity	85% RH Non-condensing



2088-9020, MR204/C, Four DPDT Relay Package with Enclosure (shown with cover removed)



Encapsulated Relay Package
(typical of 2088-9021, PAM-1 and 4098-9843, PAM-SD)

Specifications *Continued*

Encapsulated Relays, see page 2 for dimensions		
Connections		18 AWG (0.82 mm^2) color-coded wire leads
Relay 2088-9021		
Contact Ratings		10 A @ 120 VAC, resistive
Coil Ratings	Voltage	18-35 VAC/VDC, 120, or 240 VAC
	Current	15 mA @ 24 VAC/VDC, & @ 120 or 230 VAC
Relay 4098-9843		
Coil Ratings		18-32 VDC input, polarized, 15 mA @ 24 VDC
Contact Ratings		7 A at 0.35 p.f @ 28 VDC & 120 VAC
		250 μA @ 5 VDC
Temperature Ratings		
UL Listed Range		32° F to 120° F (0° C to 49° C)
Operating Range		-58° F to 185° F (-50° C to 85° C)
Humidity		85% RH Non-condensing

* Listings are under Apollo America Inc. per model numbers shown on page 2. See CSFM Listing 7300-1004:0101 for allowable values and/or conditions concerning material presented in this document.

Simplex

ULC Listed

Multi-Application Peripherals

IDNet™ Communicating Devices
Addressable Manual Stations

Features

Individually addressable manual fire alarm stations with:

- Power and data supplied via IDNet addressable communications using a single wire pair*
- Operation that complies with ADA requirements
- Pull lever that protrudes when alarmed
- Break-rod supplied (use is optional)

Multiple models are available:

- Single action operation
- Double action operation, Breakglass or Push
- Two stage pull station

For use with Simplex IDNet communications

Compact, sealed construction:

- Allows mounting in standard electrical boxes (with spacer)
- Screw terminals for wiring connections
- Reduces dust infiltration

Tamper resistant reset key lock (keyed same as Simplex fire alarm cabinets)

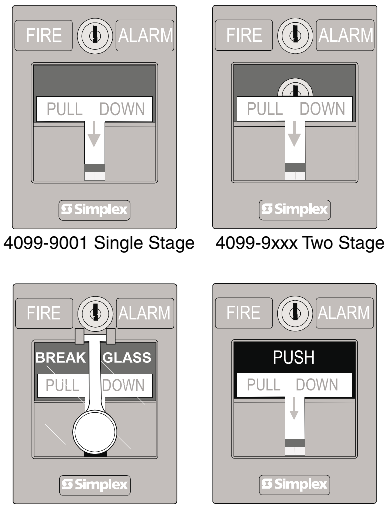
Multiple mounting options:

- Surface or semi-flush with standard or matching Simplex boxes
- Flush mount adapter available
- Adapters are available for retrofitting of existing addressable stations

Description

The Simplex 4099 Series addressable stations combine the familiar Simplex manual station housing with a compact communication module that is easily installed to satisfy demanding applications. Its integral individual addressable module (IAM) constantly monitors status and communicates changes to the connected control panel via Simplex IDNet communications wiring.

* Simplex IDNet addressable communications are protected by U.S. Patent 4,796,025.



4099-9001 Single Stage 4099-9xxx Two Stage
4099-9002 Breakglass 4099-9003 Push

Operation

Activation of the Simplex 4099-9001 single manual station requires a firm downward pull to activate the alarm switch. Completing the action breaks an internal plastic break-rod (visible below the pull lever, use is optional). The use of a break rod can be a deterrent to vandalism without interfering with the minimum pull requirements needed for easy activation. The pull lever latches into the alarm position and remains extended out of the housing to provide a visible indication.

Double Action Stations (Breakglass) require the operator to strike the front mounted hammer to break the glass and expose the recessed pull lever. The pull lever then operates as a single action station.

Double Action Stations (Push Type) require that a spring loaded interference plate (marked PUSH) be pushed back to access the pull lever of the single action station.

Station reset requires the use of a key to reset the manual station lever and deactivate the alarm switch. (If the break-rod is used, it must be replaced.)

Station testing is performed by physical activation of the pull lever. Electrical testing can be also performed by unlocking the station housing to activate the alarm switch.

Simplex

4100ES Fire Control Panels

*UL, ULC, CSFM Listed; FM Approved; MEA (NYC) Acceptance**

Addressable Fire Detection and Control
Basic Panel Modules and Accessories

Features

Master Controller (top) bay:

- 32-Bit Master Controller with color-coded operator interface including raised switches for high confidence feedback
- Dual configuration program CPU, convenient service port access, and capacity for up to 2500 addressable points
- CPU assembly includes 2 GB dedicated compact flash memory for on-site system programming and information storage
- System power supply (SPS) and charger (9 A total) with on-board: NACs, IDNet addressable device interface, programmable auxiliary output and alarm relay
- Available with InfoAlarm Command Center expanded content user interface (see data sheet S4100-0045)
- Upgrade kits are available for existing control panels

Standard addressable interfaces include:

- IDNet addressable device interface with 250 points that support TrueAlarm analog sensing and operate with *either shielded or unshielded* twisted pair wiring
- Remote annunciator module support via RUI (remote unit interface) communications port

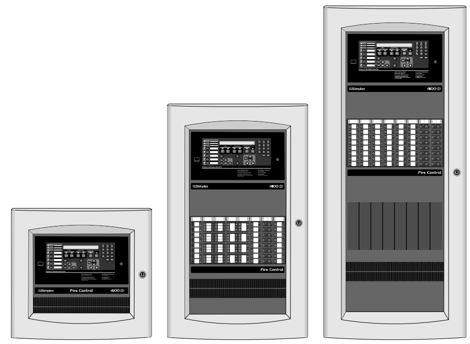
Optional modules include:

- Building Network Interface Module (BNIC) for Ethernet connectivity options (see data sheet S4100-0061)
- Additional IDNet and MAPNET II addressable device modules and IDNet/MAPNET II quad isolator modules
- IDNet+ output module with built-in quad isolator and enhanced operation for better retrofit to existing wiring (see data sheet S4100-0046)
- Fire Alarm Network Interfaces, DACTs, city connections, and up to five (5) RS-232 ports for printers and terminals
- IP communicator compatibility
- Alarm relays, auxiliary relays, additional power supplies, IDC modules, NAC expansion modules
- Service modems, VESDA Air Aspiration Systems interface, ASHRAE BACnet Interface, TCP/IP Bridges
- LED/switch modules and panel mount printers
- Emergency communications systems (ECS) equipment; 8 channel digital audio or 2 channel analog audio
- Battery brackets for seismic area protection (see page 2)

Compatible with Simplex® remotely located 4009 IDNet NAC Extenders, up to ten per IDNet SLC

4100ES and upgrade kits are UL Listed to:

- UL 864, Fire Detection and Control (UOJZ), and Smoke Control Service (UUKL)
- UL 2017, Process Management Equipment (QVAX)
- UL 1076, Proprietary Alarm Units-Burglar (APOU)
- UL 1730, Smoke Detector Monitor (UULH)
- UL 2572, Mass Notification Systems (PGWM)); refer to data sheet S4100-0034 for audio equipment
- ULC S527, Control Units for Fire Alarm Systems



4100ES Cabinets are Available with One, Two or Three Bays

Software Feature Summary

CPU provides dual configuration programs:

- Two programs allow for optimal system protection and commissioning efficiency with one active program and one reserve
- Downtime is reduced because the system stays running during download

PC based programmer features:

- Convenient front panel accessed Ethernet port for quick and easy ***download*** of site-specific programming
- Modifications can be ***uploaded*** as well as downloaded for greater service flexibility
- ***AND***, firmware enhancements are made via software downloads to the on-board flash memory

Introduction

4100ES Series Fire Detection and Control Panels provide extensive installation, operator, and service features with point and module capacities suitable for a wide range of system applications. An on-board Ethernet port provides fast external system communications to expedite installation and service activity. Dedicated compact flash memory archiving provides secure on-site system information storage of electronic job configuration files to meet NFPA 72 (*National Fire Alarm and Signaling Code*) requirements.

Modular design. A wide variety of functional modules are available to meet specific system requirements. Selections allow panels to be configured for either Stand-Alone or Networked fire control operation. InfoAlarm Command Center options provide convenient expanded display content (detailed on data sheet S4100-0045).

* See pages 5 and 6 for product that is UL or ULC listed and additional listing information. This product has been listed by the California State Fire Marshal (CSFM) pursuant to Section 13144.1 of the California Health and Safety Code. See CSFM Listing 7165-0026:251(4100ES) for allowable values and/or conditions concerning material presented in this document. Accepted for use – City of New York Department of Buildings – MEA35-93E. Additional listings may be applicable; contact your local Simplex product supplier for the latest status. Listings and approvals under Simplex Time Recorder Co. are the property of Tyco Fire Protection Products.

TrueAlert® Multi-Candela Notification Appliances

*UL, ULC, CSFM Listed; FM Approved; MEA (NYC) Acceptance**

Visible Notification Appliances with Synchronized Flash; Non-Addressable, SmartSync™ Operation Compatible

Features

Visible only (V/O) 24 VDC notification appliances with high output xenon strobe, available for wall or ceiling mount:

- Intensity is selectable as 15, 30, 75, or 110 candela with visible selection jumper secured behind strobe housing
- Operation is compatible with ADA requirements (refer to important installation information on page 3)
- Polarized input allows connection to compatible reverse polarity, supervised notification appliance circuit (NAC)
- Regulated circuit design ensures consistent flash output and provides controlled inrush current
- Rugged, high impact, flame retardant thermoplastic housings are available in red or white with clear lens
- Listed to UL 1971 and ULC S526

Strobes provide synchronized flash for use with:

- 4006, 4008, 4010, and 4100U Series fire alarm control panels with NACs selected to provide strobe synchronization or SmartSync two-wire control**
- 4009 IDNet™ NAC Extenders
- Separate strobe Synchronization Modules that are available for Class B or Class A operation
- Separate SmartSync Control Modules (SCMs) that provide Class B or Class A output from conventional NAC inputs

Strobe housings provides flexible, easy, and convenient semi-flush or surface wall mounting:

- Rear of housing does not extend into box
- Wall mount strobes easily mount to single gang, double gang, or 4-inch square outlet box
- Ceiling mount strobes mount to single gang boxes

Wall mount strobe features:

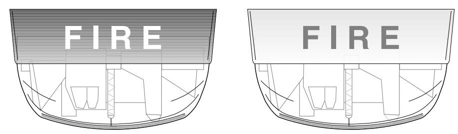
- Wiring terminals are accessible from the front of the housing providing easy access for installation, inspection, and testing
- Covers are available separately to convert housing color

Optional adapters and wire guards:

- Wall mount strobe adapters are available to cover surface mounted electrical boxes and to adapt to Simplex® 2975-9145 boxes
- UL listed red wire guards are available for wall or ceiling mount strobes*

* Refer to page 2 for guard listing. This product has been approved by the California State Fire Marshal (CSFM) pursuant to Section 13144.1 of the California Health and Safety Code. See CSFM Listing 7125-0026:316 for allowable values and/or conditions concerning material presented in this document. It is subject to re-examination, revision, and possible cancellation. Refer to page 2 for listing status of wire guards. Additional listings may be applicable; contact your local Simplex product supplier for the latest status. Listings and approvals under Simplex Time Recorder Co. are the property of Tyco Safety Products Westminster.

Wall Mount Strobes



Ceiling Mount Strobes

Description

Multi-Candela TrueAlert synchronized strobes provide convenient installation to standard electrical boxes. The enclosure designs are both impact and vandal resistant and provide a convenient strobe intensity selection. Since each model can be selected for intensity output, on-site model inventory is minimized and changes encountered during construction can be easily accommodated.

Wall mount strobe housings are a one-piece assembly (including lens) that mounts to a single or double gang, or 4" square standard electrical box. The cover can be quickly removed (a tool is required) and covers are available separately for color conversion.

Ceiling mount strobes install using standard single gang electrical boxes. Color choice is determined by model number.

Strobe Intensity Selection

During installation, a selection plug at the back of the housing determines the desired strobe intensity. An attached flag with black letters on a highly visible yellow background allows the selected intensity to be seen at the side of the strobe lens.

Strobe Application Reference

Proper selection of visible notification is dependent on occupancy, location, local codes, and proper applications of: the *National Fire Alarm Code* (NFPA 72), ANSI A117.1; the appropriate model building code: BOCA, ICBO, or SBCCI; and the application guidelines of the Americans with Disabilities Act (ADA).

** Simplex multi-candela SmartSync two-wire horn/strobe appliance operation is protected under one or more of the following U.S. Patent Numbers: 5,559,492; 5,622,427; 5,865,527; 5,886,620; 6,281,789; 6,954,137; 7,005,971; and 7,006,003.

Simplex — **True*Alert*® Multi-Candela Notification Appliances**

*UL, ULC, CSFM Listed; FM Approved; MEA (NYC) Acceptance**

Smart*Sync*™ Operation Audible/Visible Notification with Horn and Synchronized Flash, Non-Addressable

Features

Audible/visible (A/V) notification appliances with efficient electronic horn and high output xenon strobe, available for wall or ceiling mount:

- Operation is compatible with ADA requirements (refer to important installation information on page 3)
- Rugged, high impact, flame retardant thermoplastic housings are available in red or white with clear lens

Operates over a two-wire SmartSync circuit to provide:

- Horns that are controlled separately from strobes on the same two-wire circuit
- "On-until-silenced" and "on-until-reset" operation on the same two-wire pair
- SmartSync horn activation of Temporal pattern, March Time pattern (at 60 BPM), or on continuously
- Strobe appliances on the same circuit operating at a synchronized 1 Hz flash rate
- Operation requires connection to a compatible SmartSync operation NAC or to SmartSync Control Module (SCM) 4905-9938

Wall mount A/Vs features:

- Wiring terminals are accessible from the front of the housing providing easy access for installation, inspection, and testing
- Covers are available separately to convert housing color
- Optional UL/ULC listed sound damper for locations requiring attenuation of 5 to 6 dBA (stairwells, small rooms, highly reverberant areas, etc.)

Optional adapters and wire guards:

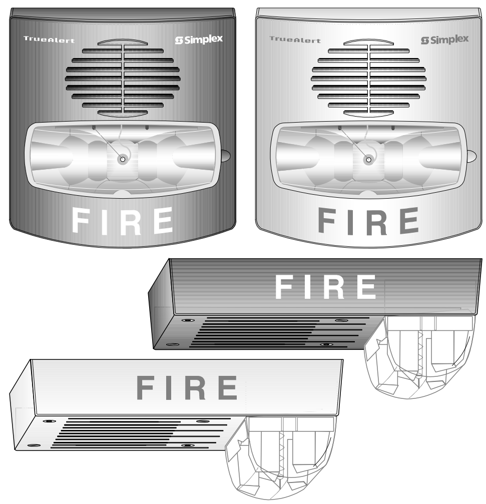
- Wall mount A/V adapters are available to cover surface mounted electrical boxes and to adapt to Simplex® 2975-9145 boxes
- UL listed red wire guards are available for wall or ceiling mount A/Vs*

Visible notification appliance (strobe):

- 24 VDC xenon strobe; intensity is selectable as 15, 30, 75, or 110 candela with visible selection jumper secured behind strobe housing
- Regulated circuit design ensures consistent flash output and provides controlled inrush current
- Listed to UL 1971 and ULC S526

Audible notification appliance (horn):

- Low current, 24 VDC electronic horn with harmonically rich sound output suitable for either steady or coded operation (Temporal or 60 BPM March Time pattern)
- Listed to UL 464 and ULC S525



Wall and Ceiling Mount A/Vs

Description

Multi-Candela TrueAlert A/Vs with horn and synchronized strobe provide convenient installation to standard electrical boxes. The enclosure designs are both impact and vandal resistant and provide a convenient strobe intensity selection. Since each model can be selected for strobe intensity output, on-site model inventory is minimized and changes encountered during construction can be easily accommodated.

Wall mount A/V housings are a one-piece assembly (including lens) that mounts to a single or double gang, or 4" square standard electrical box. The cover can be quickly removed (a tool is required) and covers are available separately for color conversion.

Ceiling mount A/Vs install using standard 4" electrical boxes. Color choice is determined by model number.

Strobe Intensity Selection

During installation, a selection plug at the back of the housing determines the desired strobe intensity. An attached flag with black letters on a highly visible yellow background allows the selected intensity to be seen at the side of the strobe lens.

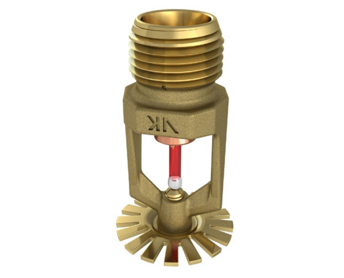
* Refer to page 2 for guard listing. This product has been approved by the California State Fire Marshal (CSFM) pursuant to Section 13144.1 of the California Health and Safety Code. See CSFM Listing 7125-0026:317 for allowable values and/or conditions concerning material presented in this document. It is subject to re-examination, revision, and possible cancellation. Accepted for use – City of New York Department of Buildings – MEA35-93E. Refer to page 2 for listing status of wire guards. Additional listings may be applicable; contact your local Simplex product supplier for the latest status. Listings and approvals under Simplex Time Recorder Co. are the property of Tyco Safety Products Westminster.

** Simplex multi-candela SmartSync two-wire horn/strobe appliance operation is protected under one or more of the following U.S. Patent Numbers: 5,559,492; 5,622,427; 5,865,527; 5,886,620; 6,281,789; 6,954,137; 7,005,971; and 7,006,003.

VIKING® | TECHNICAL DATA

MICROFAST® QUICK RESPONSE PENDENT SPRINKLER VK302 (K5.6)

The Viking Corporation, 210 N Industrial Park Drive, Hastings MI 49058
Telephone: 269-945-9501 Technical Services: 877-384-5464 Fax: 269-818-1680 Email: techsvcs@vikingcorp.com
Visit the Viking website for the latest edition of this technical data page: www.vikinggroupinc.com



WARNING: Cancer and Reproductive Harm- www.P65Warnings.ca.gov

1. DESCRIPTION

The Viking Microfast® Quick Response Pendent Sprinkler VK302 is a small thermosensitive glass bulb spray sprinkler available with various finishes and temperature ratings to meet design requirements. The special Polyester and Electroless Nickel PTFE (ENT) coatings can be used in decorative applications where colors are desired. In addition, these coatings have been investigated for installation in corrosive environments and are Listed and Approved as indicated in the Approval Charts.

2. LISTINGS AND APPROVALS

cULus Listed: Category VNIV

FM Approved: Class Series 2000

VdS Approved: Certificates G414009, G414010, G4040095, and 4880045

LPCB Approved: Certificate 096e/06

CE Certified: Standard EN 12259-1, certificate of constancy of performance 0832-CPR-S0021

CCCF Approved: Approved by the China Certification Center for Fire Products (CCCF)

MED Certified: Standard EN 12259-1, EC-certificate of conformity 0832-MED-1003

Refer to Approval Chart 1 and Design Criteria cULus Listing requirements, and refer to Approval Chart 2 and Design Criteria for FM Approval requirements that must be followed.

3. TECHNICAL DATA

Specifications:
Minimum Operating Pressure: 7 psi (0.5 bar)
Rated to 175 psi (12 bar) water working pressure
Factory tested hydrostatically to 500 psi (34.5 bar)
Thread size: 1/2" NPT, 15 mm BSP
Nominal K-Factor: 5.6 U.S. (80.6 metric**)
Glass-bulb fluid temperature rated to -65 °F (-55 °C)
Overall Length: 2-1/4" (58 mm)

*cULus Listing, FM Approval, and NFPA 13 installs require a minimum of 7 psi (0.5 bar). The minimum operating pressure for LPCB and CE Approvals ONLY is 5 psi (0.35 bar).

Material Standards:
Frame Casting: Brass UNS-C84400 or QM Brass
Deflector: Phosphor Bronze UNS-C51000 or Copper UNS-C19500
Bulb: Glass, nominal 3 mm diameter
Belleville Spring Sealing Assembly: Nickel Alloy, coated on both sides with PTFE Tape
Screw: Brass UNS-C36000
Pip Cap and Insert Assembly: Copper UNS-C11000 and Stainless Steel UNS-S30400
For Polyester Coated Sprinklers: Belleville Spring-Exposed
For ENT Coated Sprinklers: Belleville Spring-Exposed, Screw and Pipcap - ENT plated.

Ordering Information: (Also refer to the current Viking price list.)
Order Quick Response Pendent Sprinklers by first adding the appropriate suffix for the sprinkler finish and then the appropriate suffix for the temperature rating to the sprinkler base part number.
Finish Suffix: Brass = A, Chrome = F, White Polyester = M-/W, Black Polyester = M-/B, and ENT = JN
Temperature Suffix: 135 °F (57 °C) = A, 155 °F (68 °C) = B, 175 °F (79 °C) = D, 200 °F (93 °C) = E, 286 °F (141 °C) = G

VIKING® TECHNICAL DATA

STANDARD/QUICK RESPONSE EXTENDED COVERAGE UPRIGHT SPRINKLER VK532 (K11.2)

The Viking Corporation, 210 N Industrial Park Drive, Hastings MI 49058
Telephone: 269-945-9501 Technical Services: 877-384-5464 Fax: 269-818-1680 Email: techsvcs@vikingcorp.com
Visit the Viking website for the latest edition of this technical data page www.vikinggroupinc.com

1. DESCRIPTION

Viking EC/QREC Upright Sprinkler VK532 is a thermosensitive spray sprinkler available in several different finishes and temperature ratings to meet varying design requirements. The extra-large orifice produces the flows required to meet Light and Ordinary Hazard density requirements at lower pressures than standard orifice or large orifice sprinklers. The glass bulb operating element and special deflector characteristics meet the challenges of quick response extended coverage standards. Upright Sprinkler VK532 is cULus Listed as standard and quick response and FM Approved as quick response. The special Polyester and Electroless Nickel PTFE (ENT) coatings can be used in decorative applications where colors are desired. In addition, ENT coating has been investigated for installation in corrosive atmospheres. See Approval Charts.

NOTE: As of May 2018 all logos have been removed from the wrench boss.

2. LISTINGS AND APPROVALS

cULus Listed: Category VNIV

FM Approved: Class 2022

Refer to Approval Chart 1 and Design Criteria for cULus Listing requirements, and refer to Approval Chart 2 and Design Criteria for FM Approval requirements that must be followed.

WARNING: Cancer and Reproductive Harm- www.P65Warnings.ca.gov

3. TECHNICAL DATA

Specifications:

Minimum Operating Pressure: Refer to the Approval Charts.
Maximum Working Pressure: 175 psi (12 Bar). Factory tested hydrostatically to 500 psi (34.5 bar).
Factory tested hydrostatically to 500 psi (34.5 bar).
Thread size: 3/4” (20 mm) NPT
Nominal K-Factor: 11.2 U.S. (161.3 metric†)

† Metric K-factor measurement shown is in Bar. When pressure is measured in kPa, divide the metric K-factor shown by 10.0.

Glass-bulb fluid temperature rated to -65 °F (-55 °C)
Overall Length: 2-5/16 (59 mm)

Material Standards:

Sprinkler Frame: Brass UNS-C84400
Deflector: Copper UNS-C19500
Bulb: Glass, nominal 3 mm diameter
Belleville Spring Sealing Assembly: Nickel Alloy, coated on both sides with Teflon Tape
Screw: Brass UNS-C36000
Pip Cap and Insert Assembly: Copper UNS-C11000 and Stainless Steel UNS-S30400
For Polyester Coated Sprinklers: Belleville Spring-Exposed
For ENT Coated Sprinkler: Belleville Spring-Exposed, Screw and Pipcap-ENT plated.

Ordering Information: (Also refer to the current Viking price list.)

Order Viking EC/QREC Upright Sprinkler VK532 by first adding the appropriate suffix for the sprinkler finish and then the appropriate suffix for the temperature rating to the sprinkler base part number.
Finish Suffix: Brass = A, Chrome = F, White Polyester = M-/W, Black Polyester = M-/B, and ENT = JN
Temperature Suffix: 135 °F (57 °C) = A, 155 °F (68 °C) = B, 175 °F (79 °C) = D, 200 °F (93 °C) = E, and 286 °F (141 °C) = G
For example, sprinkler VK532 with a Brass finish and a 155 °F (68 °C) temperature rating = Part No. 08687AB

Available Finishes And Temperature Ratings:

Refer to Table 1.

Accessories: (Also refer to the Viking website)

Sprinkler Wrenches:

A. Standard Wrench: Part No. 05118CW/B (available since 1981)
B. Wrench for recessed pendent sprinkler: Part No. 11663W/B** (available since 2001)

**A ½” ratchet is required (not available from Viking).

Sprinkler Cabinets:

A. Six-head capacity: Part No. 01724A (available since 1971)
B. Twelve-head capacity: Part No. 01725A (available since 1971)

Appendix B: TEB Sequence of Operations Matrix

CONTROL UNIT ANNUNCIATION | NOTIFICATION | FIRE SAFETY CONTROL

SYSTEM OUTPUTS

ACTUATE COMMON ALARM SIGNAL INDICATOR
ACTUATE AUDIBLE ALARM SIGNAL
ACTUATE COMMON SUPERVISORY SIGNAL INDICATOR
ACTUATE AUDIBLE SUPERVISORY SIGNAL
ACTUATE COMMON TROUBLE SIGNAL INDICATOR
ACTUATE AUDIBLE TROUBLE SIGNAL
ACTUATE APPROPRIATE LOCATION INDICATOR
ACTUATE ALL AUDIBLE EVACUATION SIGNALS
ACTUATE ALL VISIBLE EVACUATION SIGNALS
DISPLAY / PRINT CHANGE OF STATUS
TRANSMIT ALARM SIGNAL TO SUPERVISING STATION
TRANSMIT SUPERVISORY SIGNAL TO SUPERVISING STATION
TRANSMIT TROUBLE SIGNAL TO SUPERVISING STATION
FAN SHUT DOWN
DAMPER SHUT DOWN

	SYSTEM INPUTS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	REMARKS
1	SMOKE SENSOR/DETECTOR	•	•					•	•	•		•	•																				•	•		
2	MANUAL PULL STATION	•	•					•	•	•		•	•																				•	•		
3	DUCT SENSOR/DETECTOR	•	•					•	•	•		•	•																				•	•		
4	WATERFLOW SWITCH	•	•					•	•	•		•	•																				•	•		
5	TAMPER SWITCH			•	•			•				•		•																						
6	POST INDICATOR VALVE SWITCH			•	•			•				•		•																						
7	FIRE ALARM AC POWER FAILURE					•	•					•			•																					
8	FIRE ALARM SYSTEM LOW BATTERY					•	•					•			•																					
9	OPEN CIRCUIT					•	•					•			•																					
10	GROUND FAULT					•	•					•			•																					
11	NOTIFICATION APPLIANCE CIRCUIT – CLASS A/STYLE Z:																																			
12	WIRE–TO–WIRE SHORT					•	•					•			•																					
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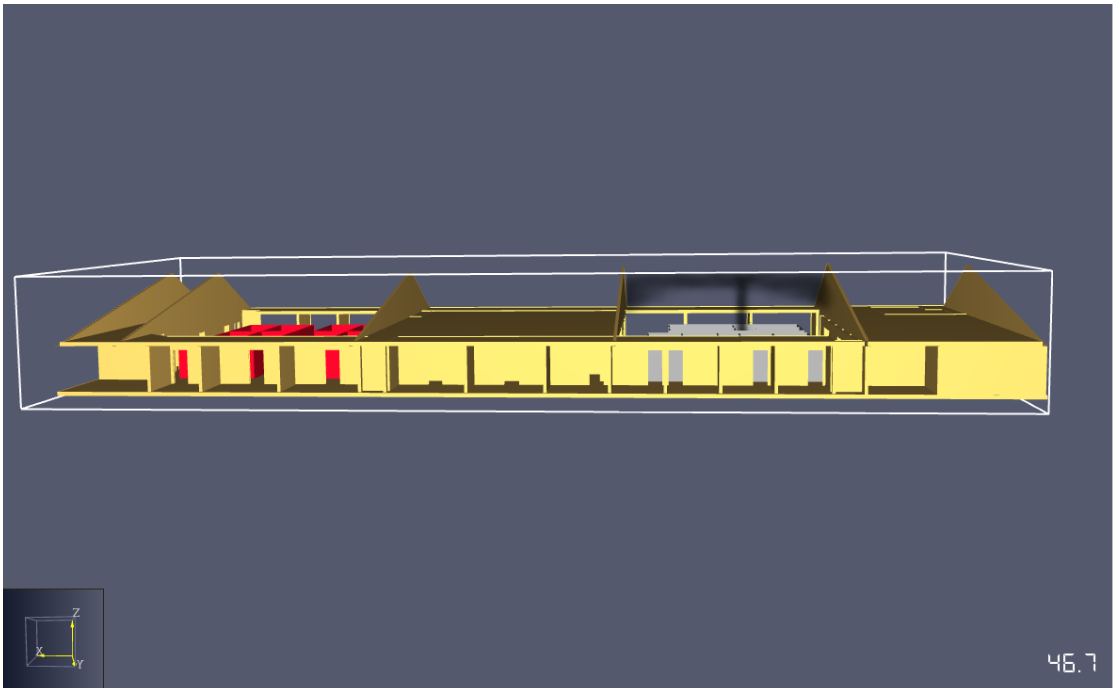
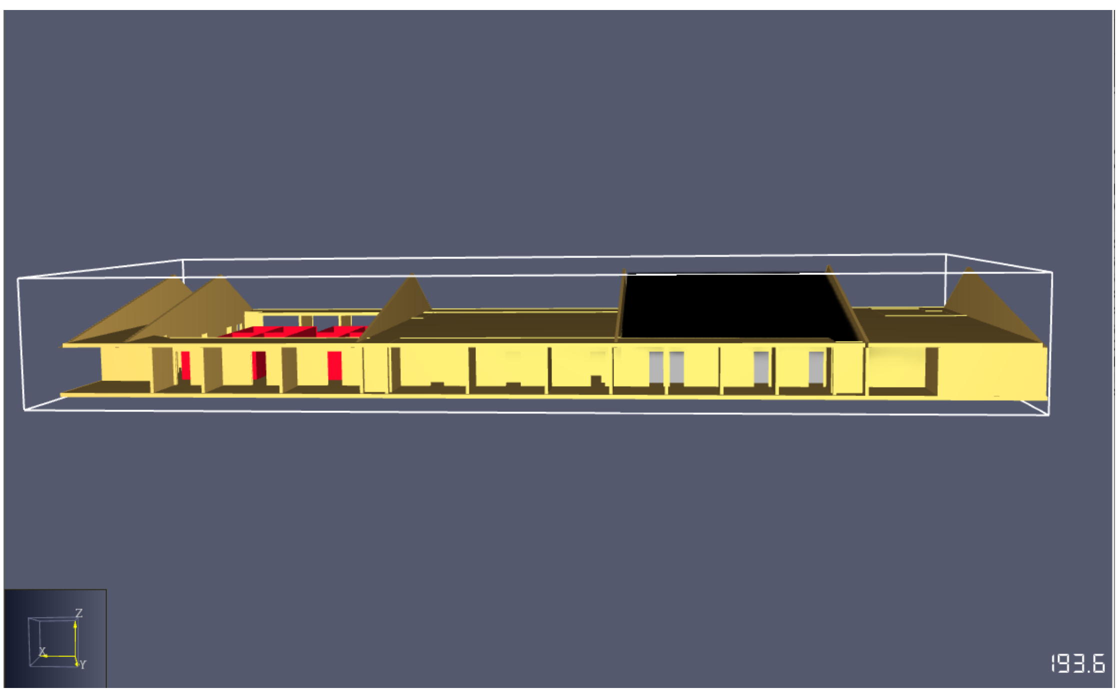
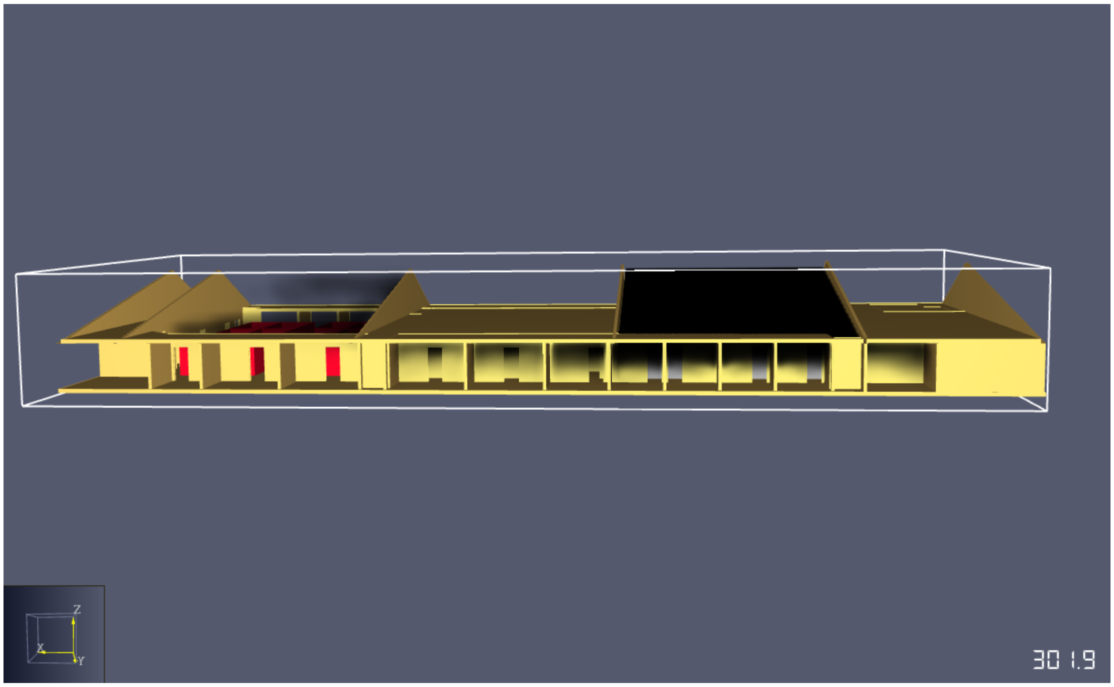
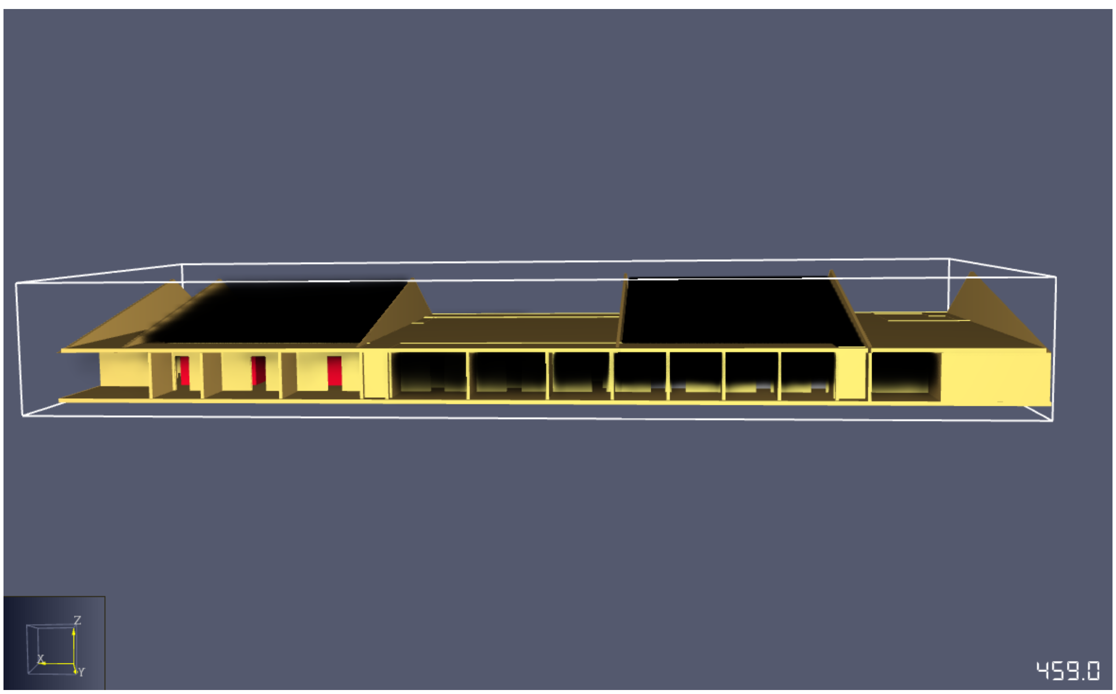
Appendix C: FDS Smoke Visualization for TEB Simulation

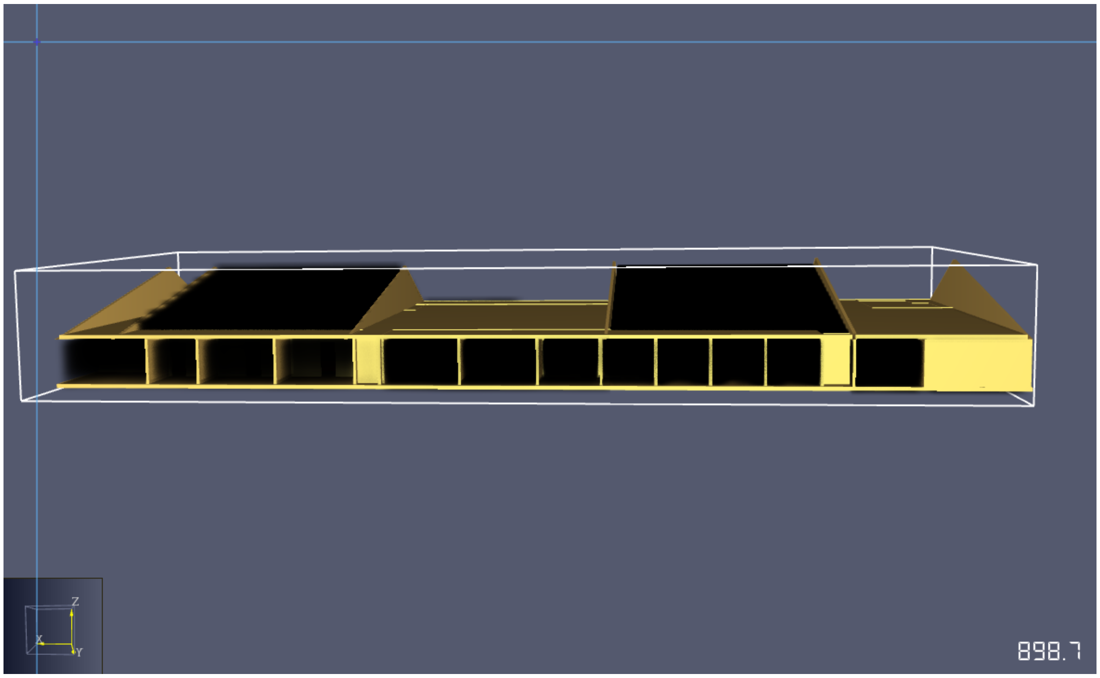
The following screenshots show the modeled progression of smoke throughout the TEB.






301.9


459.0


898.7